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SURVIVAL AND DEVELOPMENT OF *LACANOBIA SUBJUNCTA* (GROTE & ROBINSON) (LEPIDOPTERA: NOCTUIDAE) LARVAE ON COMMON WEEDS AND CROP PLANTS OF EASTERN WASHINGTON STATE

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Abstract.—Ten common weed species, four tree fruit crops and four row crops were evaluated as hosts for larvae of *Lacanobia subjuncta* (Grote & Robinson), a noctuid moth pest of apple in eastern Washington. A separate comparative evaluation was made of the suitability of five varieties of apple as hosts for *L. subjuncta* larvae. Development was completed, from neonate larva to adult, on nine of ten weed species and seven of eight crops tested, indicating a broad potential host range for this insect. High rates of survival to adult, short developmental times, and large pupal weights were noteworthy on the weeds bindweed, dandelion, and mallow, and on potato. In the comparison of apple varieties, highest rate of survival to adult was with Red Delicious, greatest pupal weights were with Red Delicious, Gala, and Fuji, and shortest development times were with Gala and Golden Delicious. Strong seasonal variation (May versus July) was indicated in the quality of apple foliage as food for *L. subjuncta* larvae.

Key Words:—Insecta, *Lacanobia subjuncta*, host plant, apple, potato.

The noctuid moth *Lacanobia subjuncta* (Grote & Robinson) has recently become recognized as a significant pest of apple in eastern Washington and Oregon (Landolt 1998). The moth is widely distributed in North America (McCabe 1980), and has been present in irrigated areas of eastern Washington at least since the 1970s when it was collected in light traps in Yakima County by F. Howell (personal communication). Following an apparent increase in damage to apple attributed to cutworms (Warner 1996), *L. subjuncta* was identified as the principal noctuid pest on apple in eastern Washington and adjacent areas of Oregon (Landolt 1998).

Lacanobia subjuncta is bivoltine (McCabe 1980), with a flight of moths from late May into mid June and again from late July into mid September in eastern Washington (Landolt 1998, Hitchcox 2000). Larvae can be found on apple trees from early June through July and again from late August until October (Hitchcox 2000). It is thought that the insect overwinters strictly as a pupa in soil. Most larvae held in the laboratory and fed on apple foliage went through 6 instars before pupating, although several larvae went through 7 (Hitchcox 2000).

On apple, larvae of *L. subjuncta* are primarily foliage feeders and occasionally partially defoliate apple trees in commercial orchards. Damage to apple fruit occurs also, with larval feeding indicated by a hollowed out scoop in the surface of the apple that is somewhat characteristic of fruit feeding by other noctuids. The pest status for *L. subjuncta* on apple is due principally to their feeding on apple fruit and to problems in packing houses because of the presence of larvae on fruit (Warner 1998).

The recently acquired pest status of this insect on apple in Washington and Oregon is not understood. Hypotheses to explain this apparent change in pest status include 1) resistance to commonly used pesticides together with escape

from natural enemies, 2) shifts in larval host plants, 3) changes in geographic distribution, 4) past misidentification of cutworms and fruit worms damaging apple, and 5) region-wide *L. subjuncta* moth population increases resulting in movement of moths into apple orchards. In order to consider the latter hypothesis, better information is needed on what plants may sustain *L. subjuncta* reproduction and may then be the principal host plants contributing to regional moth populations.

Larvae of *L. subjuncta* have been collected on a wide variety of plants, including trees, shrubs, and herbaceous plants (Godfrey 1972, Rings et al. 1992, Crumb 1956, Landolt 1998, and included references), indicating a potentially high degree of polyphagy. Recorded host plants include a number of agricultural crop plants, such as apple, cherry, peach, blueberry fruit and foliage, cabbage, asparagus, corn, and strawberry. However, the finding of larvae on a plant species is not necessarily a good indicator of suitable host plant status. The survival and development of larvae on plants along with the incidence of larvae on plants in the field would be better indicators of the importance of those plants as contributors to populations of *L. subjuncta*. In a preliminary assessment of host suitability of common weeds, Landolt (1998) demonstrated that *L. subjuncta* larvae could complete development on the weeds *Taraxacum officinale* Weber (dandelion), *Sonchus oleraceus* L. (annual sowthistle), *Convulvulus arvensis* L. (field bindweed), and *Malva neglecta* Wallr (common mallow), but with low (20 to 28) percentages that survived to the adult stage.

Reported here are the results of experiments evaluating the ability of larvae of *L. subjuncta* to develop on foliage of a larger number of plant species (18) that are commonly encountered in irrigated areas of eastern Washington. This evaluation included determination of larval survival to pupation and adult emergence, larval development time, and pupal weights for *L. subjuncta* fed on the foliage of each plant species or variety. The objective of the study was to determine if these plants sustain complete development of newly hatched larvae through to adult, and might then contribute in the field to populations of *L. subjuncta*. Additionally, this study sought to identify plant species that might be further evaluated in the field as good hosts for *L. subjuncta*.

MATERIALS AND METHODS

For each plant species and apple variety evaluated, data were obtained on survival of larvae to pupation and adult emergence, on larval development time (egg hatch to entry into soil), and on pupal weight. Plants evaluated were weed species *Sonchus asper* (L.) Hill (spiny sowthistle), dandelion, common mallow, field bindweed, *Cirsium arvense* (L.) Scop. (Canada thistle), *Helianthus annuus* L. (sunflower), *Chenopodium album* L. (lambsquarters), *Amaranthus retroflexus* L. (red-root pigweed), *Cardaria draba* (L.) Desv. (hoary cress), and *Kochia scoparia* (L.) Schrad. (kochia), the crop plants *Malus pumila* Mill. (apple, var. Fuji), *Pyrus communis* L. (pear, var. Bartlett), *Prunus armeniaca* L. (apricot), *Medicago sativa* L. (alfalfa), *Pisum sativum* L. (dry peas, var. Columbian), *Pisum sativum* L. (succulent peas, var. Oregon Trail), and *Solanum tuberosum* L. (potato, var. Russet Burbank). In another experiment, the apple varieties Fuji, Gala, Braeburn, Red Delicious, and Golden Delicious were evaluated as hosts for *L. subjuncta* larvae.

Adult *L. subjuncta* were obtained from a walk-in light trap at the Yakima

Agricultural Research Laboratory southeast of Yakima, Washington, in an area of commercial irrigated apple and pear orchards. Female moths from the light trap were held for 24 h in 50 ml plastic snap-cap vials for oviposition. Females that did not oviposit within that time period were assumed to be unmated and were moved to 900 ml plastic tubs with ventilated lids. These tubs contained sugar water on cotton balls, water on cotton balls, and two males that had been collected in the light trap. Some of these females subsequently laid fertile eggs. Newly eclosed larvae from egg batches were used for the following experiments.

The assay unit was a 300 ml waxed paper carton with a clear plastic lid, in which was placed plant foliage and one newly hatched larva. Cartons were held in a room on a 16:10 light:dark photoperiod, at 25° C and 60% RH. Plant foliage was added daily. Dried, brown, or moldy foliage was removed daily and new cartons were provided as needed when soiled by frass. When larvae reached about 3 cm in length, 2–3 cm of damp soil was placed in the carton and the plant foliage and larva were placed on top of this soil. Mature larvae entered the soil to pupate. Daily records were made of larval mortality, and larval movement into soil. Four to 6 days after larvae moved into soil, the soil was sifted to confirm the presence of a pupa, which was then weighed and transferred to a 30 ml paper cup held inside of the original waxed paper carton. Daily observations were made of pupae in order to record adult emergence. Data was not obtained on pupal duration because it was not possible to tell on what day a larva in the soil pupated. Disturbing the larva at that time might interfere with successful development.

Plant foliage was obtained in the field as needed by cutting plants with scissors and transferring foliage in 3.6 liter Ziplock® plastic freezer bags held in a cooler until return to the laboratory. Bags of foliage were held in a refrigerator at 3° C for up to seven days and were accessed daily to obtain foliage that was provided to larvae. For weeds, plants were selected from areas not sprayed with insecticides. For crop plants, growers were consulted for information on the timing and application of insecticides to avoid the collection of foliage with pesticide residues.

For each plant species or apple variety evaluated, three sets of five larvae were tested, with each set of five larvae originating from the egg batch of a different female moth. These three sets of larvae were staggered in time (three weeks apart) so that the individual plants evaluated were different for each set of five larvae.

RESULTS

Larvae of *L. subjuncta* developed to pupation and adult emergence on the following weeds: spiny sowthistle, dandelion, bindweed, lambsquarters, mallow, Canada thistle, hoary cress, pigweed, and kochia (Table 1). No larvae survived to pupation on sunflower. Highest percentages of larvae surviving to pupation were fed on field bindweed. Larvae also developed to pupation and adult emergence on the following crop plants: cherry, apple, pear, alfalfa, potato, dry peas, and succulent peas (Table 1). No larvae survived to pupation on apricot. Highest percentages of larvae that pupated were on cherry, pear, potato and alfalfa. Larvae developed to pupation and adult emergence on all 5 apple varieties tested, but with significant differences in percentage of pupation among these varieties (Table 2). Significantly more larvae on Gala apple foliage died than did on Golden Delicious foliage.

Table 1. Mean ($\pm$ SE) % pupation, adult emergence, pupal weight, and larval development times for *Lacanobia subjuncta* on 10 weedy plant and 8 crop species. Yakima, Washington, 2000.^a

Plant species	% Pupated	% Adult	Pupal weight (mg)	Larval time (days)
Hoary Cress	66.7 $\pm$ 13.3c	60.0 $\pm$ 11.5	335 $\pm$ 8c	44.3 $\pm$ 1.6a
Common Mallow	80.0 $\pm$ 11.5bc	80.0 $\pm$ 11.5	363 $\pm$ 15b	26.1 $\pm$ 0.7c
Spiny Sowthistle	60.0 $\pm$ 20.0c	60.0 $\pm$ 20.0	436 $\pm$ 10a	26.9 $\pm$ 1.3bc
Dandelion	86.7 $\pm$ 6.7b	86.7 $\pm$ 6.7	392 $\pm$ 5b	25.7 $\pm$ 1.1bc
Canada Thistle	46.7 $\pm$ 6.7d	46.7 $\pm$ 6.7	249 $\pm$ 16e	28.7 $\pm$ 1.5bc
Common Sunflower	00.0 $\pm$ 00.0e	00.0 $\pm$ 00.0	— $\pm$ —	— $\pm$ —
Lambsquarter	85.0 $\pm$ 5.0b	73.4 $\pm$ 6.7	342 $\pm$ 11c	28.4 $\pm$ 1.6bc
Redroot Pigweed	70.0 $\pm$ 10.0d	70.0 $\pm$ 10.0	280 $\pm$ 10de	35.1 $\pm$ 2.9ab
Field Bindweed	100 $\pm$ 00.0a	100 $\pm$ 00.0	374 $\pm$ 8b	25.1 $\pm$ 0.6c
Kochia	40.0 $\pm$ 11.5d	40.0 $\pm$ 11.5	270 $\pm$ 12e	35.8 $\pm$ 2.7ab
Apple	66.7 $\pm$ 6.7c	66.7 $\pm$ 6.7	389 $\pm$ 7b	25.1 $\pm$ 0.7c
Pear	100.0 $\pm$ 00.0a	100 $\pm$ 00.0	333 $\pm$ 8c	26.5 $\pm$ 0.7bc
Cherry	93.4 $\pm$ 6.7ab	86.7 $\pm$ 6.7	323 $\pm$ 12cd	30.4 $\pm$ 1.1b
Apricot	00.0 $\pm$ 00.0e	00.0 $\pm$ 00.0	— $\pm$ —	— $\pm$ —
Potato	100 $\pm$ 00.0a	100 $\pm$ 00.0	377 $\pm$ 12b	24.7 $\pm$ 0.9c
Alfalfa	100 $\pm$ 00.0a	100 $\pm$ 00.0	297 $\pm$ 8d	29.9 $\pm$ 0.9b
Dry Peas	86.7 $\pm$ 13.3b	60.0 $\pm$ 23.0	285 $\pm$ 10de	31.3 $\pm$ 1.0b
Succulent Peas	73.4 $\pm$ 17.6bc	66.7 $\pm$ 24.0	286 $\pm$ 8d	29.8 $\pm$ 0.9b

^a Means within a column followed by the same letter are not significantly different by Tukey’s test at $P > 0.05$.

Mean development rates for larvae on weeds ranged from 25.1 days on bindweed to 44.3 days on hoary cress (Table 1). Other weeds supporting rapid development of larvae were spiny sowthistle, dandelion, mallow, lambsquarter, and Canadian thistle. Mean development rates for larvae on crop plants ranged from 24.7 days for potato to 31.3 days on dry peas (Table 1). Other crops supporting rapid development were apple and pear. Among apple varieties tested, mean development times were similar for Gala, Red Delicious, Fuji and Golden Delicious, while development on Granny Smith foliage was significantly slower (Table 2). Also of interest, mean development time for larvae on Fuji apple foliage was 25.1 $\pm$ 0.7 days when evaluated in the first study and was then 38.2 $\pm$ 1.0 days when evaluated in the second study, along with other apple varieties. The first evaluation used apple foliage collected during May, while the second evaluation used apple foliage collected during July.

Table 2. Mean ($\pm$ SE) % pupation, adult emergence, pupal weight, and larval development times for *Lacanobia subjuncta* on foliage of 5 apple varieties. Yakima, Washington, 2000.^a

Apple variety	% Pupated	% Adult	Pupal weight (mg)	Larval time (days)
Gala	40.0 $\pm$ 11.5b	33.3 $\pm$ 6.7	336 $\pm$ 30ab	37.4 $\pm$ 6.6bc
Red Delicious	73.3 $\pm$ 6.7ab	73.3 $\pm$ 6.7	387 $\pm$ 9a	38.0 $\pm$ 1.0bc
Fuji	73.3 $\pm$ 13.3ab	60.0 $\pm$ 11.5	357 $\pm$ 8ab	38.2 $\pm$ 1.0b
Golden Delicious	80.0 $\pm$ 20.0a	60.0 $\pm$ 11.5	321 $\pm$ 12b	35.7 $\pm$ 1.0bc
Granny Smith	66.7 $\pm$ 13.3ab	50.0 $\pm$ 10.0	284 $\pm$ 22b	47.7 $\pm$ 2.1a

^a Means within a column followed by the same letter are not significantly different by Tukey’s test at $P > 0.05$.

Mean pupal weights for *L. subjuncta* reared on weeds ranged from 249 mg on Canada thistle to 436 mg on spiny sowthistle (Table 1). Other relatively heavy mean pupal weights were 392 mg for larvae reared on dandelion, 374 mg for larvae reared on bindweed, and 363 mg for larvae reared on mallow. In addition to Canada thistle, pigweed and kochia yielded low pupal weights (Table 1). Mean pupal weights for larvae fed crop plants ranged from 285 mg for dry peas to 377 mg for potato and 389 mg for Fuji apple (Table 1). When mean pupal weights for apple varieties were compared, they ranged from 284 mg for larvae fed Granny Smith to 387 mg for larvae fed Red Delicious apple foliage (Table 2).

DISCUSSION

These results clearly indicate a broad potential plant host range for *L. subjuncta* larvae and the potential for many plants in eastern Washington to contribute to regionally high population densities contributing to crop losses. Complete development from egg hatch to adult emergence was documented for 9 of the 10 weeds tested and 7 of the 8 crops tested, with sunflower and apricot not supporting larval development to pupation in this study. The plants selected for this study and supporting *L. subjuncta* development are taxonomically diverse and include the families Compositae, Cruciferae, Chenopodiaceae, Convulvulaceae, Malvaceae, Solanaceae, Rosaceae, and Leguminaceae. Undoubtedly, many other plants present in the region are probably equally suitable as hosts for *L. subjuncta*.

Just as the collection of larvae on a plant species is not proof that the species is a good host plant, the demonstrations of survival and development to adult on these plant species does not demonstrate that *L. subjuncta* utilizes these plants. Additional information on patterns of adult female egg laying, of larval dispersal and movement under field conditions, and of larval numbers on these and other plant species would be more conclusive in assessing the potential of these plants as hosts. Such studies clearly should incorporate not only common weeds but additional crops that have not been reported to be infested with *L. subjuncta*.

There were differences in the performance of larvae on Fuji apple foliage collected in May versus July that indicate possible seasonal variation in the suitability of foliage of apple as food for *L. subjuncta* larvae. There are two broods of *L. subjuncta* in Washington, with most larvae feeding in June/July and again in August/September (Hitchcox 2000). Larvae reared on Fuji apple foliage in May developed more rapidly and yielded larger pupae than larvae reared on Fuji apple in July. Despite these possible differences in apple suitability as a host for *L. subjuncta*, larvae are readily found on apple in the field during both time periods (Hitchcox 2000). Such differences in host suitability could be due to a variety of factors, such as accumulated leaf chemical defenses, increases in average leaf age, accumulated responses to disease and herbivore challenges, and nutritional changes in leaves. There is potential for much variation in foliage quality as food for larvae for each of the plant species tested and care must be exercised in using the data presented here for comparative purposes among plant species.

Also of concern is the potential impact of the apparent variance of plant suitability as food for *L. subjuncta* larvae on phenology models used in IPM programs for apple orchards. Such models may be used to predict *L. subjuncta* egg hatch for the purpose of accurately timing pesticide applications. If larval development rates are dependent in part on seasonal parameters affecting plant physiology,

these must be incorporated into insect developmental models. Also, differential rates of development on different host plants will contribute to variance in adult emergence, oviposition, and egg hatch when multiple plants are used as hosts.

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**A NEW SPECIES OF *HETEROSPILUS* (HYMENOPTERA:
BRACONIDAE) ASSOCIATED WITH THE DEATHWATCH
BEETLE, *HEMICOELUS GIBBICOLLIS* (LECONTE)
(COLEOPTERA: ANOBIIDAE)**

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Abstract.—*Heterospilus luridostigmus* Marsh, a new braconid wasp species, is described. This wasp was found in abundance emerging from pieces of Douglas-fir, *Pseudotsuga menziesii* (Mirbel) Franco, from an outdoor wooden deck in Daly City, California, that was infested with the deathwatch beetle, *Hemicoelus gibbicollis* (LeConte). Adult *Heterospilus luridostigmus* began emerging in May 1999 followed by emergence of *Hemicoelus gibbicollis* about 4 weeks later. Both species continued to emerge throughout the summer of 1999 and were the only species found in the boxes. During the summer of 2000, rearing boxes containing infested wood from the original source and from several homes in Alameda County, California yielded both *Heterospilus luridostigmus* and *Hemicoelus gibbicollis* as well as *Odontocolon polymorphum* Cushman (Hymenoptera: Ichneumonidae). Although we found no direct evidence of parasitism of *Hemicoelus gibbicollis*, wasps in the genera *Heterospilus* and *Odontocolon* are known to parasitize anobiids, and *Heterospilus flavicollis* (Ashmead) is a parasitoid of an eastern deathwatch beetle species, *Hemicoelus carinatus* (Say). This suggests that *Heterospilus luridostigmus* is a parasitoid of *Hemicoelus gibbicollis*. The synchrony of emergence of these two species during both years also is indicative of a host/parasitoid relationship between the two species. The discovery of a new insect species in a heavily populated urban environment is noteworthy and serves as a vivid reminder of the untold number of insect species that have yet to be discovered.

Key Words.—Insecta, Braconidae, Anobiidae, Ichneumonidae, deathwatch beetle, parasitoid, emergence hole.

The genus *Heterospilus* Haliday is a member of the braconid subfamily Doryctinae. It can be identified by using the key to New World genera of Braconidae (Marsh 1997). In North America the genus is easily distinguished from the other doryctine genera by the reduction of fore wing vein 2RS (Fig. 1), which is always desclerotized and often completely absent, and the presence of a stigma in the hind wing of the male (not pictured). The small genus *Pioscelus* Muesebeck and Walkley, which also has fore wing vein 2RS absent, is separated by having no basal tubercle on the hind coxa. *Heterospilus* is the most species-rich genus in the Doryctinae, with an estimated 200 species in the Nearctic Region and 300 in the Neotropical Region. Most of these species are undescribed and the genus is badly in need of revision.

All *Heterospilus* are idiobiont ectoparasitoids (Shaw & Huddleston 1991) and this genus also has the most diversified host range in the Doryctinae. Species of the genus parasitize a very wide range of endophytic, mostly stem-boring, hosts

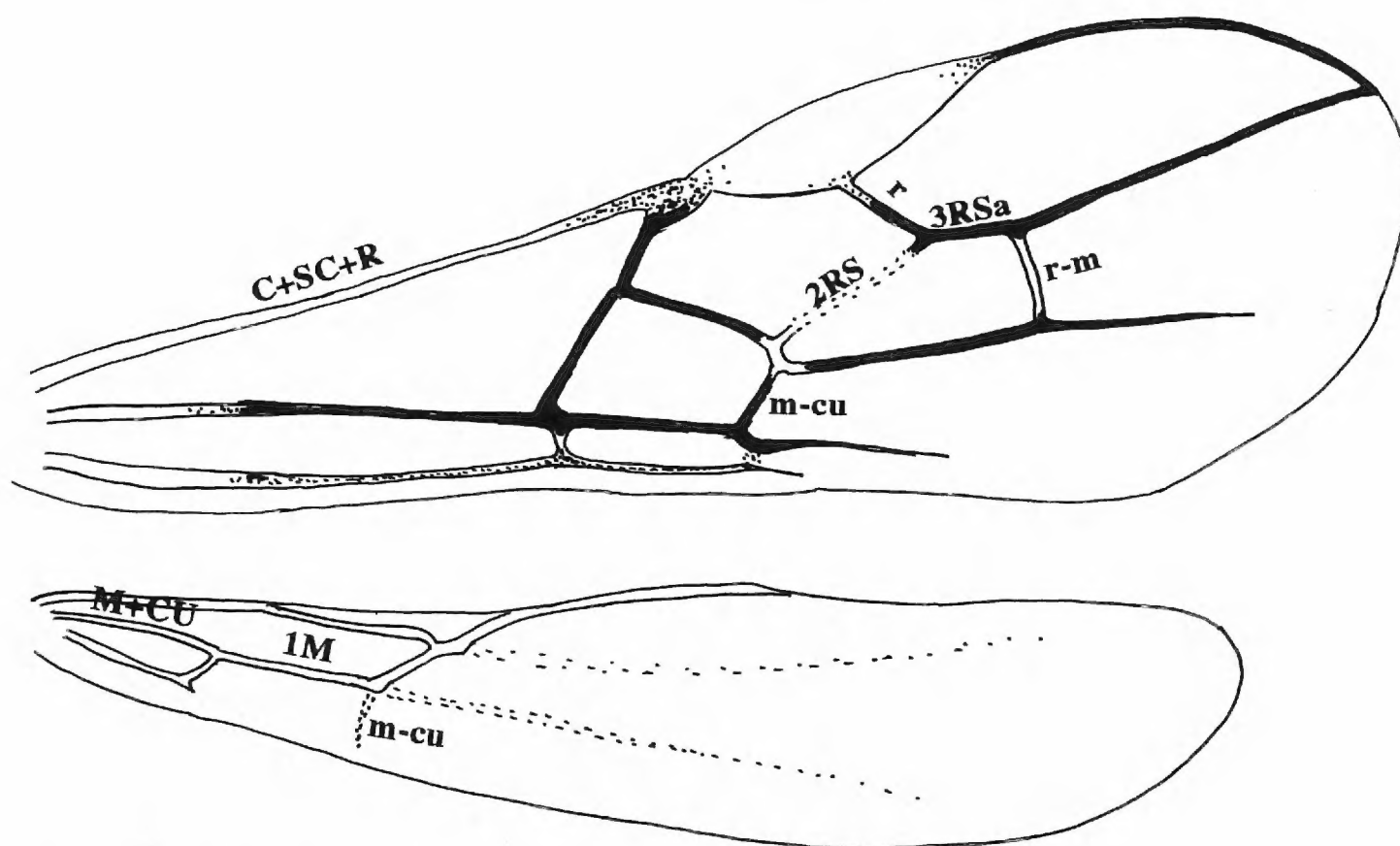


Figure 1. Wing venation of female *Heterospilus luridostigmus*, n. sp.

(Marsh 1982, Shaw 1995) including those in the coleopteran families Anobiidae, Bostrichidae, Bruchidae, Buprestidae, Cerambycidae, Curculionidae, Languriidae, Mordellidae and Scolytidae, and those in the lepidopteran families Gelechiidae, Incurvariidae, Pyralidae and Tortricidae. Several other species have been reared from other hosts including stem-boring symphytan Hymenoptera. A few species are known to attack pemphredonine sphecid wasps (Marsh & Melo 1999).

In North America, five species have been recorded from Anobiidae, including the new species described in this paper whose authorship is attributed solely to P. M. Marsh. V. R. Lewis obtained beetle-infested wood was obtained by V. R. Lewis. Wasps and beetles were reared and collected by V. R. Lewis and B. J. Cabrera. S. J. Seybold and V. R. Lewis are principal investigators on a deathwatch beetle, *Hemicoelus gibbicollis* (LeConte), pheromone project that includes the work presented in this paper.

HETEROSPILUS LURIDOSTIGMUS MARSH, NEW SPECIES

Types.—Holotype, female. CALIFORNIA: SAN MATEO CO.: Daly City, 393 Oriente St., Oct. 1998, V. R. Lewis, ex *Pseudotsuga menziesii* (Mirbel) Franco boards from wooden deck. Deposited in NMNH, Washington, D.C.

Paratypes.—CALIFORNIA: same data as holotype, 41 females, 7 males. Deposited in the California Academy of Sciences, San Francisco, NMNH, Washington, D.C. and the University of Minnesota Insect Collection, University of Minnesota, St. Paul.

Description.—*Female*. Color: head, mesosoma and metasoma dark brown; scape, pedicel and basal flagellomeres light brown, apical flagellomeres dark brown; fore and middle legs yellow, femora marked with raised brown spot dorsomedially, tibiae marked with brown; hind leg with coxa and femur brown, trochanters yellow, tibia yellow marked with brown, tarsus yellow; wings slightly dusky, veins brown, stigma and vein C+SC+R light yellow, stigma sometimes nearly white. Body size: 2.5–

4.0 mm. Head: face smooth and with dense long gold hair, frons and vertex transversely striate (Fig. 2), occasionally weakly so and nearly smooth; temple smooth; malar space two-thirds eye height; ocell-ocular distance about 3 times diameter of lateral ocellus; occipital carina not meeting hypostomal carina; 19–23 antennomeres. Mesosoma: pronotum rugose, with dense gold hair along weak pronotal groove; mesonotal lobes (Fig. 3) coriaceous, rugose along notauli, notauli scrobiculate, meeting before scutellum in rugose area with longitudinal short carinae, dense long gold hair along notauli; scutellum smooth; mesopleuron smooth, subalar area carinate, sternaulus deep and longitudinally striate, dense long gold hair on subalar area and along posterior edge; propodeum (Fig. 4) rugose, basal median areas smooth, median carina and areola distinct, dense gold hair laterally. Legs: hind coxa with small but distinct antero-ventral basal tubercle or tooth. Wings (Fig. 1): fore wing vein r as long as or slightly longer than 3RSa, vein 2RS indicated by weak infuscate line, vein r-m not sclerotized but distinct, vein m-cu arising distad from vein 2RS; hind wing vein M+CU longer than vein 1M, vein m-cu a distinct infuscated line. Metasoma (Fig. 5): first tergum longitudinally carinate, length slightly less than apical width, median raised area distinct, defined by carinae only on basal half; second tergum longitudinally carinate; third tergum smooth with carinate area across basal half; remainder of tergum smooth; ovipositor about two-thirds length of metasoma.

Male.—Essentially as in female; body size 1.5–3.0 mm; 17–20 antennomeres; hind wing with elongate stigma.

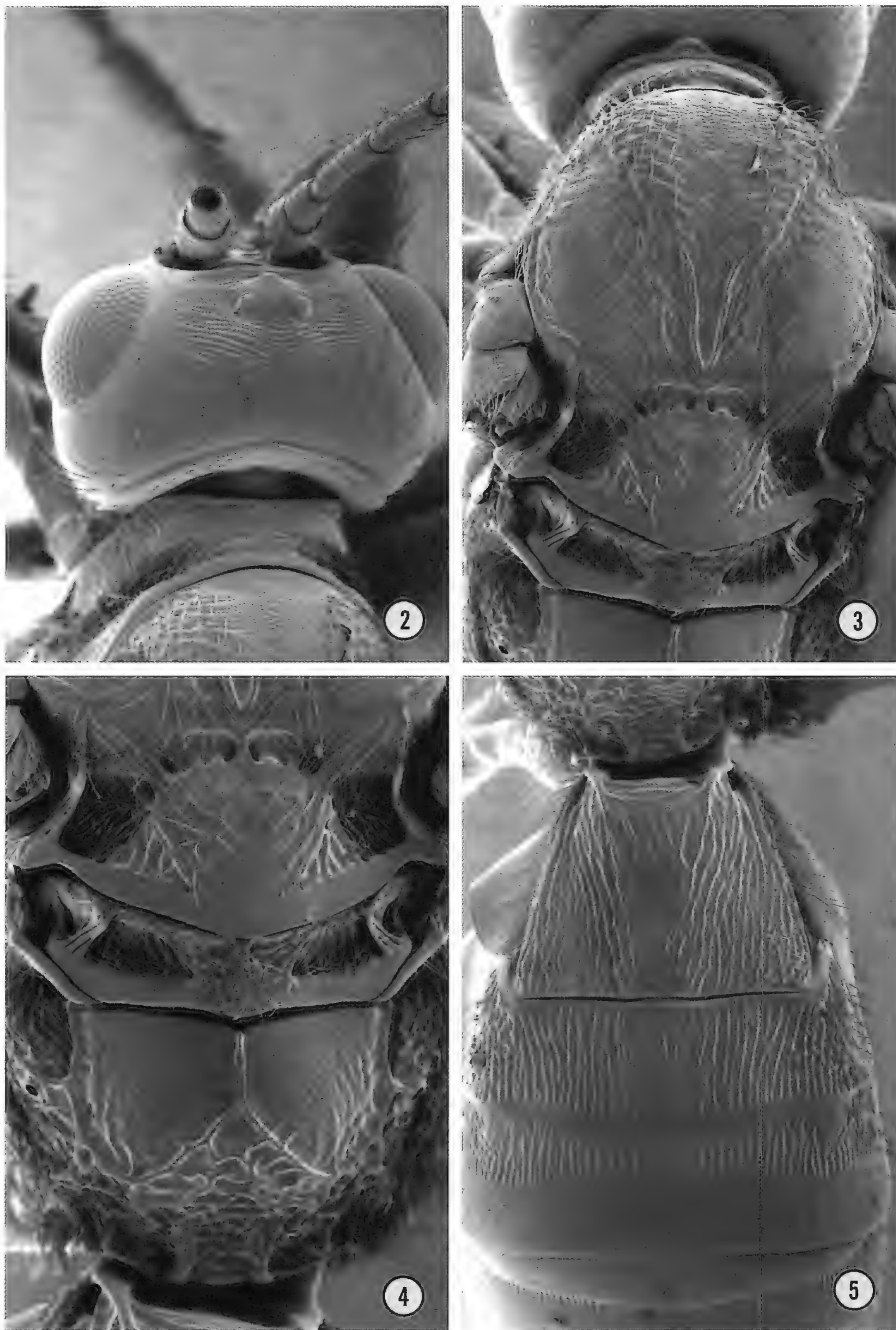
Biology.—Associated with adults of *Hemicoelus gibbicollis* (LeConte) (Coleoptera: Anobiidae) infesting Douglas-fir boards from a backyard deck. See details of biology below.

Comments.—This species is distinctive by its light yellow to almost white stigma in the fore wing and by vein M+CU in the hind wing being longer than vein 1M. Although this hind wing venation is not typical for the genus, in all other characters the specimens are clearly congeneric. This species is easily distinguished from *H. baeticatus* (Provancher), *H. flavicollis* (Ashmead) and *H. longicauda* (Ashmead), which are also recorded as parasitoids of anobiids, by having the ovipositor shorter than the metasoma. This species has a similar ovipositor length to *H. anobiidivorus* Muesebeck but differs in the light stigma, completely carinate second metasomal tergum, shorter first metasomal tergum and longer antenna.

Etymology.—The specific name is from the Latin *luridus* meaning pale yellow in reference to the pale yellow or almost white stigma in the fore wing.

BIOLOGY AND OBSERVATIONS

Wood Collection.—Wood [Douglas-fir, *Pseudotsuga menziesii* (Mirbel) Franco] infested with the deathwatch beetle, *Hemicoelus gibbicollis*, was collected in October 1998 from the deck of a home in Daly City, San Mateo County, California. The wood was cut into lengths of approximately 20–50 cm and stored at ambient temperature and relative humidity in a greenhouse at the University of California, Berkeley, in two wooden emergence boxes (122 × 122 × 122 cm) or in 58 liter plastic storage boxes with 5-cm diameter screen-covered holes in each end for ventilation. Wood moisture content was monitored with a moisture meter (Protimeter Timbermaster, Protimeter Ltd., Marlow Bucks, England) and the wood was watered as needed to maintain approximately 14–17% moisture content (Suomi & Akre 1992a, b). Additional pieces of infested wood (predominantly *P. menziesii*) were collected in October, 1999 from several homes in Alameda County, California and kept outdoors on the premises of the University of California, Forest Products Laboratory, Richmond, California. In June 2000, this wood was also cut and stored in plastic storage boxes as previously described.



Figures 2–5. Morphological characters of *Heterospilus luridostigmus*, n. sp. Figure 2. Vertex and frons. Figure 3. Mesonotum. Figure 4. Propodeum. Figure 5. Metasomal terga 1–4.

Beetle and Wasp Emergence, 1999.—Boxes were checked occasionally for adult *Hemicoelus gibbicollis* (needed for extracting sex pheromone and for behavioral assays) beginning in April 1999. *Heterospilus luridostigmus* appeared unexpectedly in the wooden emergence boxes on 3 May and continued to emerge through 2 Aug (Fig. 6A). The exact date of initial emergence is unknown because the boxes were not examined on a regular basis. The first *Hemicoelus gibbicollis* adults were found on 28 May with the exact date of emergence also unknown. The last adults were collected on 16 August. This emergence was in agreement with Suomi & Akre (1993a, b) who stated that normal emergence occurs during June, July, and August. We collected a total of 584 beetles (336 alive, 57.5% survival) and 179 wasps.

Beetle and Wasp Emergence, 2000.—Beetles and wasps were first collected on 15 June. The number of emerged adults of both species was considerably lower than in 1999 (Figs. 6A and 6B), possibly because of the different collection source, differences in the host wood, or because of exposure to sub-optimal environmental conditions prior to rearing. The wood had been kept outdoors for seven months before it was cut and placed in the rearing boxes. A total of 218 beetles (132 alive, 60.6% survival) and 32 wasps were collected. Several adult male and female *Odontocolon polymorphum* Cushman (Hymenoptera: Ichneumonidae) were collected in addition to *Heterospilus luridostigmus*.

Possible Parasitism of Hemicoelus gibbicollis.—The doryctine braconids are generally considered to be ectoparasitoids of wood-boring beetle larvae (Marsh 1979). However, Suomi & Akre (1992a, b, c; 1993a, b) did not mention parasitoids in their detailed descriptions of *Hemicoelus gibbicollis* biology and ecology. Furthermore, we did not directly observe wasps emerging from any life stage of *Hemicoelus gibbicollis* or from the wood and dissection of several small pieces of wood did not yield any parasitized larvae. The need for large numbers of adult *H. gibbicollis* made us reluctant to conduct a more thorough search that would have required destruction of more beetle-infested wood. However, we believe that *Heterospilus luridostigmus* is a parasitoid of *Hemicoelus gibbicollis* because: 1) adults of both species appeared in our rearing boxes in relative synchrony during both years; 2) a broad range of hole diameters was observed on the surface of the infested wood; and 3) other species of *Heterospilus* are idiobiont ectoparasitoids of wood-destroying anobiids (e.g., *Heterospilus flavicollis* (Ashmead) on *Hemicoelus carinatus* (Say) [Drooz 1985], the most common wood-infesting deathwatch beetle in the northeastern United States [Simeone 1962], and *Heterospilus longicauda* (Ashmead) on *Xyletinus peltatus* (Harris) [Williams et al. 1979]).

The only two live insect species to appear in 1999 in our rearing boxes were *Heterospilus luridostigmus* and *Hemicoelus gibbicollis*. Both species were collected again in 2000 from rearing boxes containing wood that was collected both years. In 1999, adult *Heterospilus luridostigmus* were first observed approximately four weeks before the first emergence of *Hemicoelus gibbicollis* while the following year both species were first found on the same day. Peak emergence of both species was nearly synchronous in 1999, with the largest number of wasps emerging approximately two weeks before the largest number of beetles emerged (Fig. 6A). A similar trend was observed the following summer (Fig. 6B). The observation that *Heterospilus luridostigmus* preceded *Hemicoelus gibbicollis* in

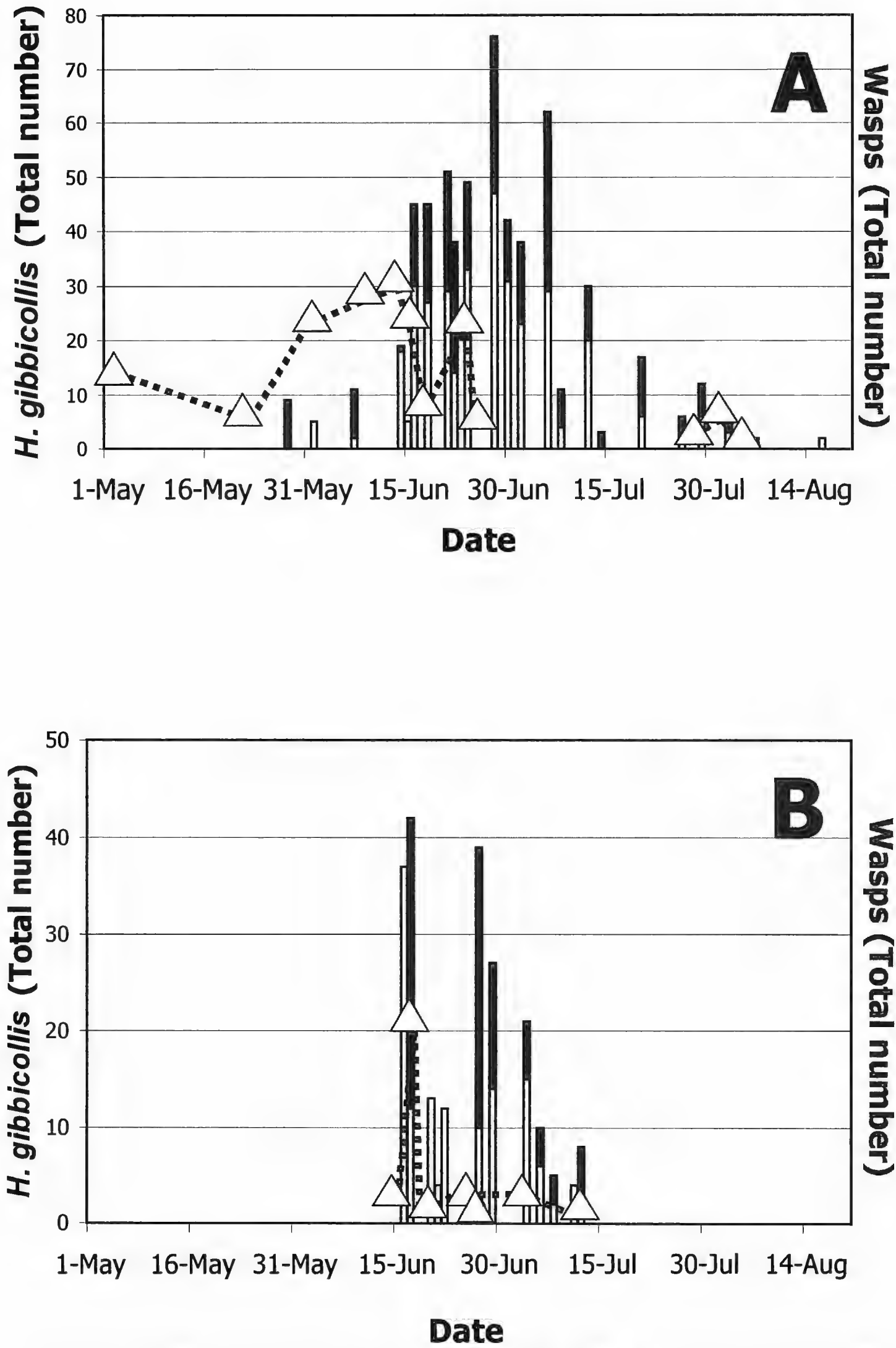


Figure 6. Emergence of beetles and wasps. A. *Hemicoelus gibbicollis* (LeConte) (bars), and *Heterospilus luridostigmus* Marsh (line), summer 1999. □ Live beetles, ■ Dead beetles, △ Live wasps. B. *Hemicoelus gibbicollis* (LeConte)(bars), and *Heterospilus luridostigmus* Marsh and *Odontocolon polymorphum* Cushman (line), summer 2000. □ Live beetles, ■ Dead beetles, △ Live wasps.

emergence in 1999 but not in 2000 might be attributed to laboratory worker inexperience, as both species are difficult to find amongst the pieces of wood in the rearing boxes. *Hemicoelus gibbicollis* is especially difficult to locate because emerged adults spend large periods of time seeking refugia in emergence holes. We also expected a much larger emergence of *Hemicoelus gibbicollis* during the summer of 2000. Dissection of several infested pieces of wood in mid-August of that year yielded beetle larvae of mixed size and, presumably, age, indicating that the infestations were still active. We speculate that the lower number of emerged beetles and the shorter emergence period during the second year were partly a result of parasitism. Williams et al. (1979) found that *Heterospilus longicauda* (Ashmead) accounted for 1.3–36.6% mortality of the potential population of their anobiid host, *X. peltatus*.

We frequently observed small emergence holes in the infested wood, presumably made by *Heterospilus luridostigmus*, adjacent to much larger and more abundant emergence holes, presumably made by *Hemicoelus gibbicollis* (Fig. 7) (*Hemicoelus gibbicollis* is considerably larger than *Heterospilus luridostigmus* in cross-sectional area). Williams et al. (1979) reported that *Heterospilus longicauda* emergence holes were about one-eighth the size of *X. peltatus* emergence holes, that the wasp oviposited through the wood and onto the host larvae, and assumed there was one parasite larva per host. However, we measured holes ($n = 434$) from several pieces of wood collected in 1999 and instead of an expected bimodal distribution we obtained an approximately normal distribution ranging from 0.46 to 2.15 mm in diameter (Fig. 8). The lack of a distinct separation among emergence hole diameters prevents us from reporting species-specific emergence hole size ranges at this time. In contrast to Williams et al. (1979), our minimum emergence hole sizes all exceeded one-eighth of the maximum hole sizes. Our sample of emergence holes probably also contained holes made by *O. polymorphum*.

The appearance of *O. polymorphum* from our rearings in 2000 reveals the possible existence of other parasitoids of *Hemicoelus gibbicollis*. The wood in the rearing boxes had been lying outdoors for seven months, thus making larvae and pupae of *H. gibbicollis* within the wood readily accessible to attack by *Heterospilus luridostigmus* and other opportunistic natural enemies. Alternatively, *Heterospilus luridostigmus* and *O. polymorphum* may have located and colonized *Hemicoelus gibbicollis* while the wood was still in the structures from which it was removed. *Odontocolon polymorphum* has been collected in Oregon, Washington, and British Columbia and has been associated with two wood-infesting anobiid species (one unidentified, the other *Ptilinus basalis* LeConte) (Carlson 1979).

This paper represents the first report of *O. polymorphum* associated with *Hemicoelus gibbicollis*. Ovipositor length and examples of other xoridine ichneumonids (Townes et al. 1960) suggest that *O. polymorphum* is ectoparasitic and oviposits through the wood surface onto larvae and pupae of *H. gibbicollis*.

Whether *H. gibbicollis* is an obligate or facultative host for both wasp species remains to be determined. Although there is strong evidence for a host/parasitoid relationship between *Hemicoelus gibbicollis* and *Heterospilus luridostigmus*, direct observation of wasp oviposition behavior, emergence of adult wasps from the host or infested wood, detection of parasitized beetle larvae or larval beetle

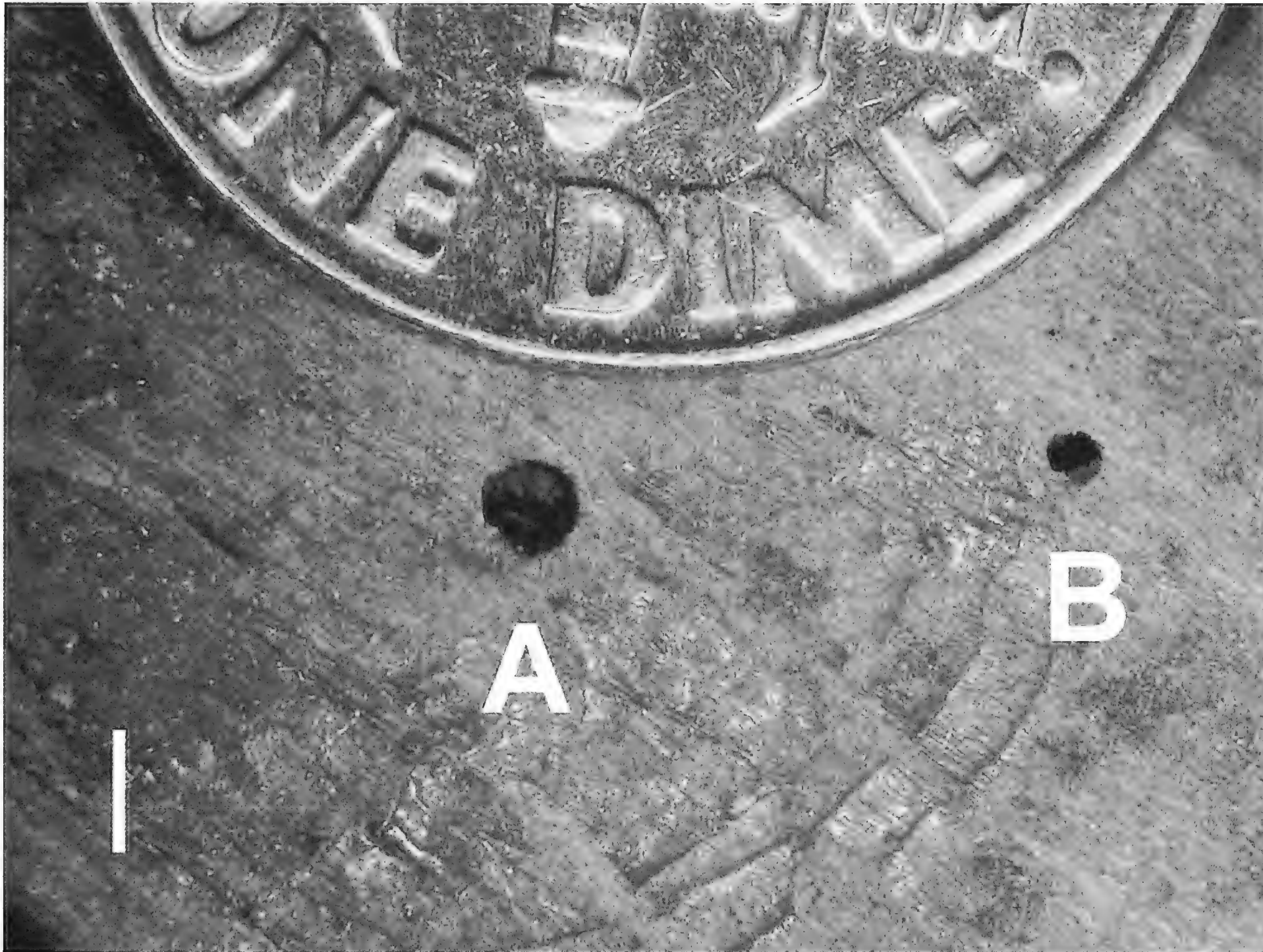


Figure 7. Adult emergence hole of *Hemicoelus gibbicollis* (LeConte) (A) and suspected emergence hole of *Heterospilus luridostigmus* Marsh (B). Bar = 1 mm.

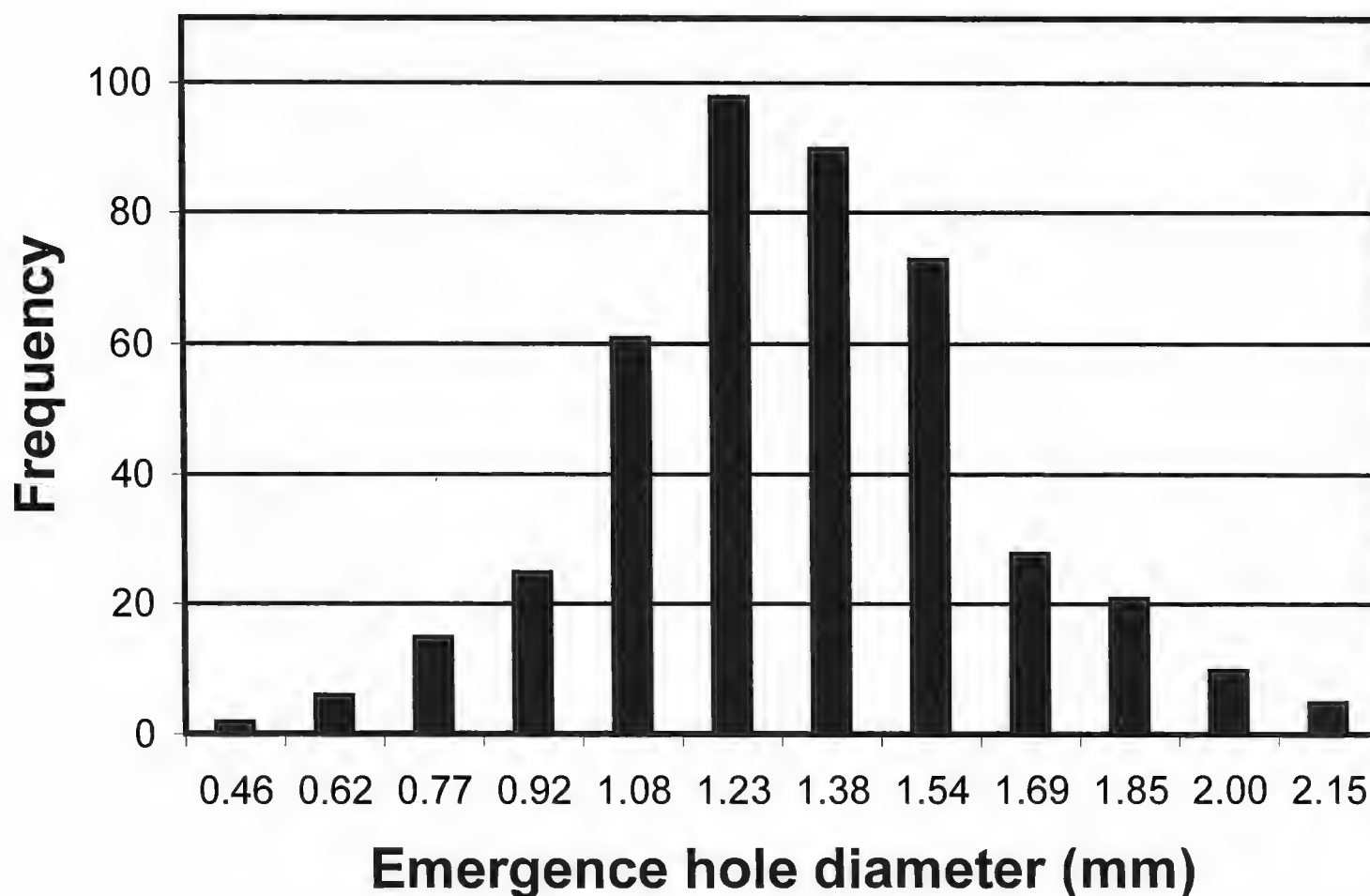


Figure 8. Size distribution of emergence holes ($n = 434$) of *Hemicoelus gibbicollis*, *Heterospilus luridostigmus*, and *Odontocolon polymorphum* measured from several pieces of infested *Pseudotsuga menziesii*, collected in 1999 in Alameda Co., California.

head capsules present in wasp cocoons is needed to confirm the existence of this proposed ecological relationship.

Finally, it is noteworthy that a new insect species has been found in an urban environment. This discovery, in a heavily populated area and in close association with human dwellings, is a vivid reminder of the tremendous diversity of the Insecta and of the untold number of insect species that have yet to be discovered.

ACKNOWLEDGMENT

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A NEW SPECIES OF *YELICONES* CAMERON (HYMENOPTERA: BRACONIDAE) FROM THAILAND

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Abstract.—*Yelicones siamensis* Areekul & Quicke, NEW SPECIES is described and illustrated based on two adult females collected at light in Thailand. This wasp is the ninth species of *Yelicones* described from the East Palaearctic and Oriental regions. A modification to the key of Quicke et al. (1997: J. Nat. Hist. 31: 779–797) is included to differentiate *Y. siamensis* from similar species.

Key Words.—Insecta, Hymenoptera, Braconidae, *Yelicones*, Thailand.

Wasps of the genus *Yelicones* Cameron are solitary endoparasitoids of lepidopteran larvae, whose remains they mummify before pupating within the host (Quicke & Chishti 1997). For many years after its original description (Cameron 1887) the genus was known only from a handful of specimens from the New World (Shenefelt 1975, Quicke & Kruft 1995). However, over the last 20 years a number of new species have been described, extending the known range of *Yelicones* into the Indo-Australian, Afrotropical and Palaearctic regions. The genus is now known to be widely distributed throughout the Old and New Worlds (Fischer 1961, 1962 [as *Pectenopius* Fischer]; Togashi 1980; Papp 1985, 1989, 1991, 1992; Belokobylskij 1993a, b; Quicke & Kruft 1995; Quicke et al. 1996, 1997, 1998; Quicke & Chishti 1997; Shaw 1998).

In this paper a new species of *Yelicones* is described based on two female specimens from Thailand, the ninth for the East Palaearctic and Oriental regions (Quicke et al. 1997). It is being described because it has been used to generate DNA sequence data which will be published elsewhere as part of another study. Male morphology and biology are unknown. The genus *Yelicones* can be recognized using the keys of van Achterberg (1995), Chen and He (1997) or Shaw (1997). A brief diagnosis is provided below.

MATERIALS AND METHODS

Two specimens were collected by light trapping in Chon Buri, Thailand and preserved in absolute alcohol. Three legs on one side of the body were taken from the paratype specimen for DNA sequencing and both specimens were then mounted for description and photography. Measurements were made with an eye-piece micrometer graticule. Terminology follows van Achterberg (1979, 1988) and Quicke et al. (1997).

Genus *Yelicones* Cameron, 1887

Yelicones Cameron 1887: 387; van Achterberg, 1995: 147 (literature). Type species, *Yelicones violaceipennis* Cameron, designated by Viereck (1914).

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Figure 1. *Yelicones siamensis* NEW SPECIES, female holotype.

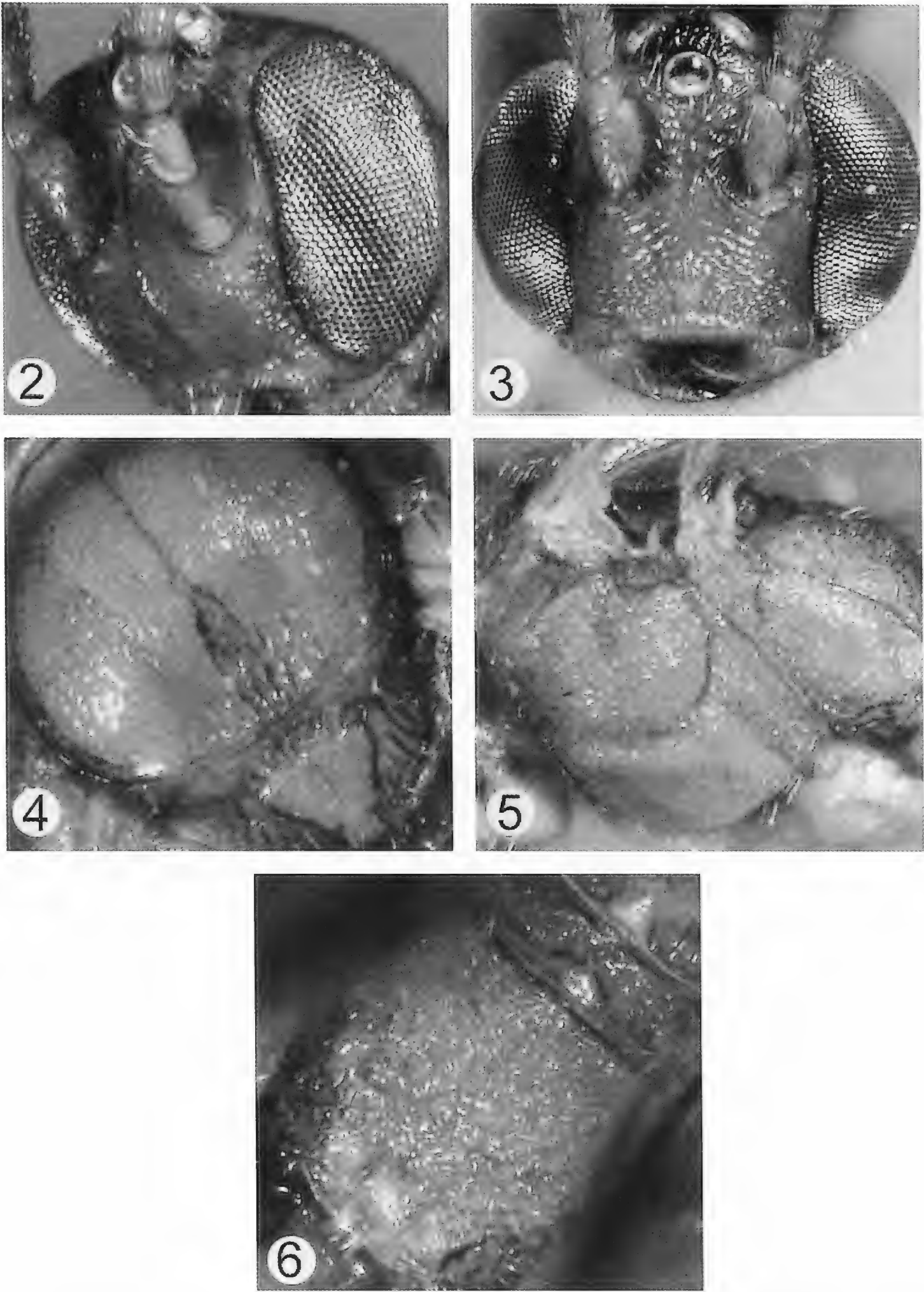
Rhopalotoma Cameron 1911: 318. Type species, *Rhopalotoma crassitarsis* Cameron, monotypic.

Pectenopius Fischer 1961: 156. Type species, *Pectenopius paradoxus* Fischer, original designation.

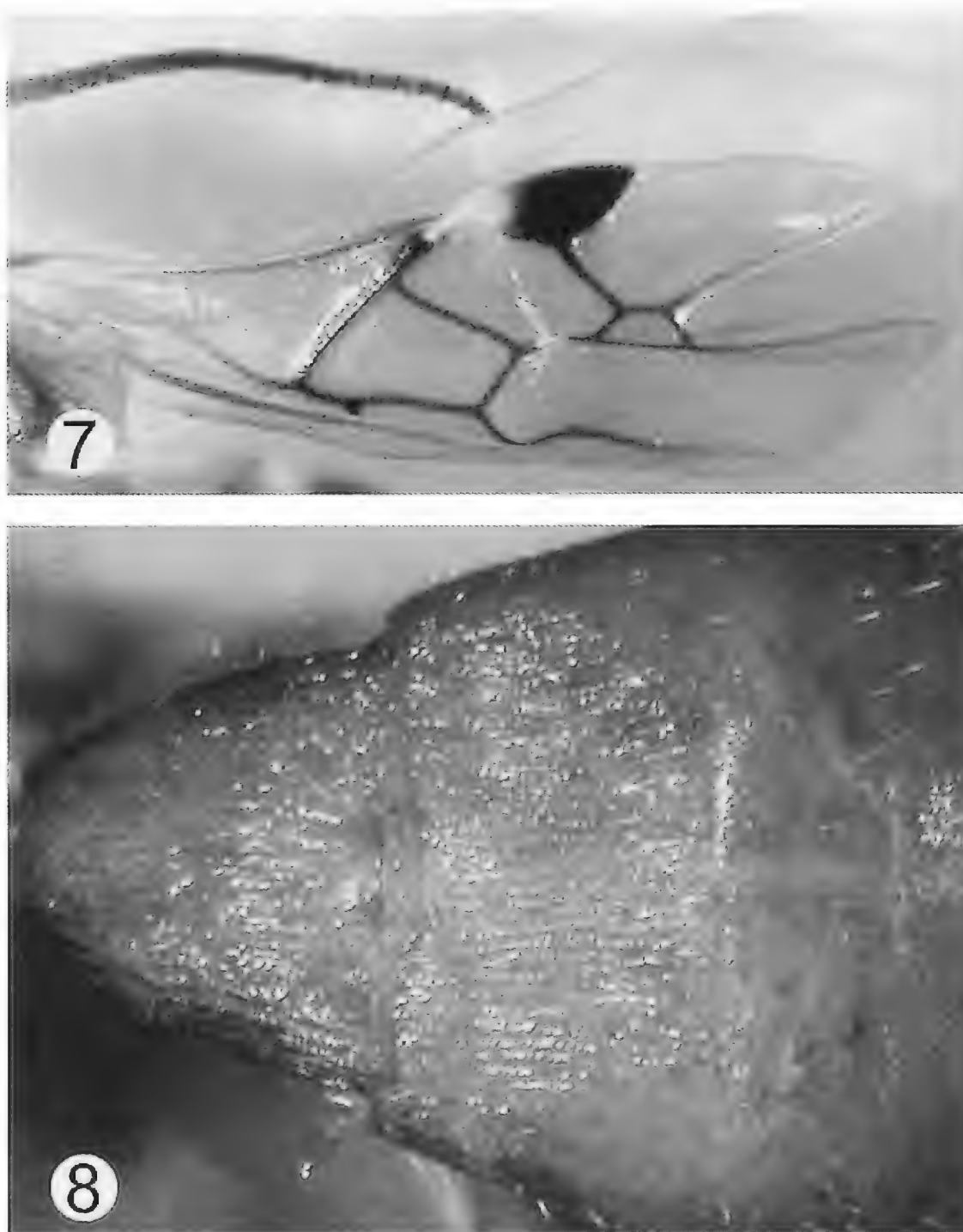
YELICONES SIAMENSIS AREEKUL & QUICKE, NEW SPECIES

Types.—Holotype, female (Fig. 1); data: THAILAND. *CHON BURI*: Khao Kheow, 20–31 March 2001, D. L. J. Quicke and N. Laurenne, light trap; deposited: British Museum (Natural History). Paratype: same data as holotype, 1 female; deposited Insect Collections of Chulalongkorn University, Bangkok, Thailand.

Description.—Female (holotype) *Length*. Body 4.5–5.0 mm, and fore wing 3.5 mm. (Fig. 1). *Color*. Yellow, antennae yellow basally, gradually brown on distal 0.4; wing veins dark brown, pterostigma basal 0.4 ivory, distal 0.6 dark brown (Fig. 1). *Head*. Antennae with 26 flagellomeres, terminal flagellomere pointed, approximately 2.3× longer than wide; first flagellomere 1.1× and 1.4× longer than the second and third respectively; first flagellomere 1.4× longer than wide; third flagellomere as long as wide; malar space unsculptured, length of malar space 0.04× height of eye; height of clypeus: inter-tentorial distance: tentorio-ocular distance = 1.0: 3.4: 0.8; clypeus slightly punctate, with long, dense setae; face with subtransverse carinae below the antennal sockets, punctate ventrally (Fig. 2), densely covered with long setae, with weak but distinct mid-longitudinal ridge (Fig. 3); height of eye: width of face: width of head = 1.0: 0.9: 1.7; length of face = 0.5× width of face; eyes glabrous; frons with sparse, long setae, impressed behind the antennal socket, mid-longitudinal ridge strongly developed, posteriorly with two curved transverse carinae; occiput and temples densely punctate; horizontal length of eye: horizontal length of head behind eye = 1.6: 1.0; post-ocellar length: trans-



Figures 2–6. *Yelicones siamensis* NEW SPECIES. Figure 2, front view of head. Figure 3, front and lateral aspect of head. Figure 4, mesoscutum. Figure 5, lateral view of prothorax. Figure 6, propodeum.



Figures 7–8. *Yelicones siamensis* NEW SPECIES. Figure 7, fore wing. Figure 8, dorsal view of metasomal tergites 1–3.

verse diameter of posterior ocellus: shortest distance between posterior ocellus and eye = 1.0: 2.0: 2.7; occipital carina nearly complete, absent for a small distance medially. *Mesosoma*. Shiny, densely punctured and setose, 1.8× longer than high; mesoscutum postero-medially with longitudinal groove-like impressions (Fig. 4); notauli weakly impressed throughout length of mesoscutum; scutellar sulcus with 7 carinae between the two outer ones; scutellum shiny and sparsely setose with small punctures; median area of metanotum medially without pit (Fig. 6); mesopleuron densely setose, with transverse carinae anteriorly, densely punctate posteriorly; precoxal suture weakly impressed, crenulate, upcurved posteriorly, impressed 0.8 length of mesopleuron (Fig. 5); propodeum strongly aerolate-rugose, antero-medially without a prominent U- or V-shaped carina (Fig. 6). *Wings*. *Fore wing*—length of veins SR1: 3SR: r = 3.3: 0.4: 1.0; vein 1-SR+M more or less straight; vein r arising 0.5 distance from base of pterostigma; length of veins 2-SR: 3-SR: r-m = 1.0: 1.0: 1.1; length of veins 2-SR+M: 2-M: m-cu = 1.0: 0.7: 0.7; length of veins 2-CU1: 3-CU1 = 2.4: 1.0; veins C+SC+R and 1-SR forming an angle of 60° (Fig. 7). *Hind wing*—length of veins 1r-m: SC+R1 = 1.0: 1.8; vein 2-SC+R interstitial; vein SR posteriorly weak, more or less straight at apex; vein 2m-cu strongly postfurcal, length of vein 1M 4.4× vein 2M, vein 2m-cu more or less straight; marginal cell, basal cell and base of wing densely setose. *Legs*. Length of fore femur: tibia: tarsus = 1.0: 1.3: 1.0; fore femur 2.0× longer than maximum depth; fore tibia without mid-longitudinal ridge; hind femur 2.7× longer than maximum depth; length of hind femur: tibia: basitarsus = 1.8: 2.5: 1.0; hind basitarsus 3.4× longer than maximally depth.

Metasoma. Metasomal tergites shiny, first and second tergite with sparse setae, 3rd–8th tergites moderately setose; first and second tergite with punctate-rugulose sculpture; first metasomal tergite 1.3× wider than medially long, dorsal carina weakly impressed, uniting before the level of spiracles; second metasomal tergite 2.4× wider than medially long, without smooth triangular area anteriorly and without mid-longitudinal carina; second suture narrow, smooth; third metasomal tergite 2.4× wider than medially long; third tergite anteriorly finely punctate, posteriorly smooth (Fig. 8); 4th–6th metasomal tergites smooth. Tip of ovipositor pale.

Diagnosis.—*Yelicones siamensis* Areekul & Quicke keys out to couplet 8 using the key to East Palearctic and Oriental species of *Yelicones* (Quicke et al. 1997). It can be distinguished from *Y. flavus* Chen and Quicke by the following characters: face not transversely imbricate; mesoscutum postero-medially rugose; fore wing vein 1-SR+M more or less straight not sinuous; hind wing vein 2-SC+R interstitial not transverse; dorsal carinae of first metasomal tergite uniting anteriorly not near mid-length, without median carina; second metasomal tergite anterior-medially without smooth triangular area and mid-longitudinal carina; color yellow, wings without distinct pattern of brownish blotches, pterostigma bicolored not unicolorous.

Modification to the key to the species of *Yelicones* of the East Palearctic and Oriental region (Quicke et al. 1997) to accommodate the new species.

- 8(7). Mesoscutum with line of notauli piceous on anterior two thirds and usually with a dark line connecting them in front of the posterior margin; propleuron and fore coxae whitish *Y. koreanus* Papp
 - Mesoscutum uniformly yellow-brown; propleuron and fore coxae brownish yellow 8a
 8a(8). Forewing with distinct pattern of brownish blotches; pterostigma uniformly, pale brown; antennae with 33 flagellomeres; second metasomal tergite antero-medially with smooth triangular area
 *Y. flavus* Chen and Quicke
 - Forewing without distinct pattern of brownish blotches; pterostigma bicolored, whitish basally, brown distally; antennae with fewer than 33 flagellomeres; second metasomal tergite antero-medially without smooth triangular area *Y. siamensis* NEW SPECIES

Variation in Females.—Body length 4.5–6.0 mm; antennae with 26–28 flagellomeres; mesoscutum postero-medially with punctate-rugose sculpture or longitudinal groove-like impressions; scutellar sulcus with 6–7 carinae between the outer ones.

Male.—Unknown.

Distribution.—Thailand.

Etymology.—The name is derived from the old name for Thailand.

Material Examined.—See Types.

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THE SPIDER FAUNA ASSOCIATED WITH LITTER UNDER WOODRAT MIDDENS IN SOUTHERN CALIFORNIA (ARACHNIDA: ARANEAE)

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Abstract.—Litter from under wood rat (*Neotoma* sp.) middens from southern California, was sampled, primarily between 1977–1985, in search of latridiid beetles. As an ancillary by-product, spiders were collected, separated and labeled with collection data but most have remained undetermined until now. In this paper, we determine the spider species associated with the rat middens, predominantly from five southern Californian counties, ranging in elevation from 200 to 1900 m. This study yielded 316 specimens representing 42 species, 34 genera and 20 families of spiders. The family Linyphiidae was represented here with the greatest number of genera, species and specimens. The most frequently collected species, *Tapinocyba dietrichi* Crosby & Bishop (Linyphiidae), contributed 37.3% of the specimen total. *Spirembolus erratus* Millidge (Linyphiidae) and *Zanomys californica* (Banks) (Amaurobiidae) were the second and third most predominant species, contributing 16.5% and 5.1%, respectively, of the specimen total. Many of the specimens identified in this study are members of minute species (1–3 mm), which can easily be overlooked unless samples are carefully scrutinized. Some of the more interesting and uncommon species include *Trogloneta paradoxum* Gertsch (Mysmenidae), *Gertschanapis shantzi* (Gertsch) (Anapidae), several *Zanomys* spp., and members from the families Hahniidae, Caponiidae and Oonopidae. Specimens collected here will contribute to the description of three new species (2 amaurobiids, 1 linyphiid) and the male of a second linyphiid species.

Key Words.—Arachnida, *Neotoma*, rat middens, species list, Araneae, spiders.

Woodrats of the genus *Neotoma* create large middens composed of vegetation and other materials culled from the surrounding environment (English 1923). Middens can reach massive sizes, primarily through occupancy by successive generations with each occupant adding material. In so doing, the rats create a microhabitat that often differs from the immediate surrounding area in various biotic and abiotic aspects (Vestal 1938, Linsdale & Tevis 1951). Dimensions of 301 middens in northern California averaged 118 cm in height and 152 cm in basal diameter; the average volume of 572 middens was 0.713 m³ (Vestal 1938). Active rat middens are strewn with fresh food cuttings and copious fecal pellets (Linsdale & Tevis 1951). Considering their structural features, middens provide ideal harborage for a plethora of animals including spiders (Linsdale & Tevis 1951). Fossil midden remains have offered a wealth of data on the historical plant and arthropod components of the regions of occupancy (Hall et al. 1989, Elias et al. 1992, Clark & Sankey 1999) although, in these studies, arachnids were represented solely by the hard-bodied ticks, scorpions and pseudoscorpions.

From 1977 to 1985, Ken Cooper of the University of California-Riverside (UCR) harvested arthropod inhabitants from the litter under *Neotoma* nests in search of beetles of the family Latridiidae. This litter was collected primarily from five southern Californian counties in a variety of habitats ranging from the Los Angeles-San Diego basins (ca. 300 m elevation) to the surrounding inland and coastal mountains (up to 1900 m). An ancillary by-product of the collections resulted in an accumulation of spiders which, until now, have languished in the

UCR Entomology museum, mostly as undetermined specimens. We have identified these spiders, the majority of which were less than 3 mm in body length, and present our findings here.

Minute spiders pose several problems that impede identification. Size alone creates difficulties in manipulation of the specimens as well as in distinguishing the pertinent diagnostic characters. Most of the minute species determined in this study are members of the Linyphiidae which contains a cumbersome number of genera and species that are often very difficult to identify. Relatively few generic keys and current taxonomic revisions are available for this family; those that do exist often include only regional fauna. One of the most current and definitive identification guides for North American spiders (Roth 1993) presents keys to genera for every family except the Linyphiidae which are simply listed alphabetically by genus for both the linyphiine (45 genera) and erigonine (117 genera) spiders. What we hope to accomplish here is to assist future investigators of *Neotoma* biology, add to our knowledge of Californian linyphiid distribution, and encourage eager arachnologists to pursue taxonomic studies on the little-known genera.

MATERIALS AND METHODS

All information regarding the history of the spiders from the *Neotoma* middens was derived from personal communications with the collector (K. Cooper), the processor (F. Andrews) of the midden material, and the former curator (S. Frommer) of the Entomology museum collection (all former associates of UCR). Approximately 100 *Neotoma* (mostly *N. fuscipes* with a few *N. lepida*) middens were sampled. The litter under each nest was shoveled into canvas bags, brought back to the laboratory and processed in approximately 12 gallon loads, for up to 10 days, in Berlese funnels until no additional arthropods were collected. Although most of the spiders were part of the undetermined UCR Entomology Research Museum spider collection, it was not known how many spiders were actually identified and incorporated as determined species. Consequently, we searched the entire general spider collection (> 1700 vials) excepting the orb-weaver families Araneidae, Tetragnathidae, Uloboridae, the adults of which we felt would not likely be using the litter under rat middens as refugia. As a result of our search, we believe that this study represents an accurate inventory of the material recovered by the researchers.

Spiders were present in samples from at least 50 *Neotoma* middens collected by Cooper in southern California. Also included are data from one midden from San Bernardino County, California collected by Andrews, Hardy & Eichlin in 1985. Elevations not present on the collection labels were approximated to the nearest 25 meters with topographic maps or through recent communications with K. Cooper and should be accurate to within 50 meters. Spiders are listed in Table 1 in decreasing frequency by family to show the importance of their ecological association with *Neotoma* nests and then alphabetically by genus within each family; families with equal numbers of specimens are grouped alphabetically.

All specimens have been incorporated into the reference collection of the UCR Entomology Research Museum.

Table 1. List of the spiders identified from *Neotoma* rat nests.

Family/Genus	Species	Male	Fem	Imm	County	Date	Elevation (meters)	Locale
Linyphiidae								
<i>Ceratinops</i>	inflatus	2	2		Riverside	14-Jan-83	1800	0.8 km E of James Reserve, San Jacinto Mts
<i>Ceratinopsis</i>	interventa		1		Kern	23-Sep-81	800	Red Rock Cyn campsite
"Ceratinopsis"	palomara		1		Riverside	30-Apr-81	750	Bautista Cyn, 27.4 km SE of Valle Vista
	palomara		2		Riverside	29-Apr-82	300	Clinton Keith Rd, W Murrieta near entrance to cyn
	palomara	1	5		Riverside	14-Jan-83	1825	0.8 km E of James Reserve, San Jacinto Mts
<i>Linyphantes</i>	aeronautica		1		Riverside	27-Dec-79	400	Whitewater Cyn
	aeronautica	1			Riverside	25-Mar-82	500	Hemet, Motte Reserve
	laguna		1		San Diego	13-Mar-81	1075	San Felipe
	microps	1			Riverside	25-Mar-82	500	Hemet, Motte Reserve
<i>Spirembolus</i>	demonologicus		2		San Diego	13-Mar-81	1075	San Felipe
	erratus	1			Riverside	13-Jan-77	1100	Bautista Cyn, 27.4 km SE of Valle Vista
	erratus		1		Riverside	13-Feb-77	600	Harford Preserve, Gavilan Hills
	erratus		9		Riverside	20-Mar-77	600	Gavilan Hills
	erratus	10	14	1	Riverside	27-Dec-79	400	Whitewater Cyn
	erratus	1			Riverside	18-Nov-83	200	Vail Lake
	erratus	1	1		Riverside	18-Nov-83	200	Vail Lake
	erratus	1			Riverside	18-Nov-83	200	Vail Lake "nest 2"
	erratus	1	9		San Bernardino	26-Feb-77	525	E of Mentone
	erratus		1		San Bernardino	13-May-82	700	Baldy Mesa, Phelan & Transmission Line Rd
	erratus		1		Santa Barbara	11-Aug-83	1075	Figueroa Mt Rd
	hibernus		1		Riverside	24-Aug-83	950	El Carrizo Oaks
	hibernus		1		San Diego	13-Mar-81	1075	San Felipe
	redondo		1		San Bernardino	2-May-68	325	1.6 km E of Summit on Rt 138
<i>Tapinocyba</i>	dietrichi	8	7		Los Angeles	11-Nov-80	1000	0.8 km N of Jct. Vasquez & Bouquet Cyns
	dietrichi	6	6		Los Angeles	14-Aug-81	1000	Bouquet Cyn nr. SE arm Bouquet Reservoir
	dietrichi	1			Los Angeles	20-Apr-82	1000	Bouquet Cyn Rd at E. end Bouquet Cyn Reservoir
	dietrichi		6		Los Angeles	20-Apr-82	1000	3.2 km E toward Palmdale on Bouquet Cyn Rd
	dietrichi	1			Los Angeles	20-Apr-82	1000	Bouquet Cyn nr. entrance Vasquez Rd
	dietrichi	2	24		Riverside	14-Jan-83	1825	James Reserve Lk Fulmor
	dietrichi	1	1		Riverside	4-Jun-83	750	7 km SE of Sage on R3
	dietrichi	1			Riverside	24-Aug-83	950	El Carrizo Oaks

Table 1. Continued.

Family/Genus	Species	Male	Fem	Imm	County	Date	Elevation (meters)	Locale
	dietrichi		3		San Bernardino	2-May-68	325	1.6 km E of Summit on Rt 138
	dietrichi	5	5		San Bernardino	3-Jun-81	975	18.6 km from Hwy 15 on Rt 138 nr Little Horse-thief Ranch
	dietrichi		3		San Bernardino	1-May-85	1100	Summit Vly under cottonwood
	dietrichi	4	16		San Diego	25-Jul-79	1250	William Heise Co. Park, Pine Hills S of Julian
	dietrichi	1	2		San Diego	13-Mar-81	1075	San Felipe
	dietrichi	1	1		San Diego	13-Mar-81	725	San Felipe @ S2
	dietrichi	5	8		Santa Barbara	11-Aug-83	1075	Figueroa Mt Rd, 1.6 km W Rngr Sta
	sp. #1		1		Riverside	17-Jun-77	1300	Covington Flat
	sp. #1		7		Riverside	9-Dec-81	1325	Joshua Tree Natl Pk, Hidden Valley
	sp. #1		4		San Bernardino	21-May-82	975	6.4 km N of Yucca Valley
Amaurobiidae								
<i>Amaurobius</i>	latescens		1		San Bernardino	26-Feb-77	525	E of Mentone
<i>Zanomys</i>	californica		1		Los Angeles	11-Nov-80	1000	0.8 km N of Jct. Vasquez & Bouquet Cyns
	californica		1		Riverside	13-Jan-77	1100	Bautista Cyn, 27.4 km SE of Valle Vista
	californica	4			Riverside	14-Jan-83	1825	James Reserve Lk Fulmor
	californica		3		Riverside	14-Jan-83	1825	0.8 km E of James Reserve, San Jacinto Mts
	californica	1			Riverside	18-Nov-83	200	Vail Lake "nest 2"
	californica		1		San Bernardino	2-May-68	325	1.6 km E of Summit on Rt 138
	californica		1		San Bernardino	3-Jun-81	975	18.6 km from Hwy 15 on Rt 138 nr Little Horse-thief Ranch
	californica		1		San Bernardino	1-May-85	1100	Summit Valley
	californica	1			San Bernardino	14-Apr-85	1850	Wrightwood
	californica		1		San Diego	25-Jul-79	1250	William Heise Co. Park, Pine Hills S. Julian
	californica		1		San Diego	25-Apr-80	1075	San Felipe
	ochra		1		San Bernardino	15-May-78	1900	Burns Cyn above Rimrock
	ochra		2		San Bernardino	13-May-82	700	Baldy Mesa, Phelan & Transmission Line Rd
	ultima		3		Santa Barbara	11-Aug-83	1075	Figueroa Mt Rd
	sp. #1	4	7		Riverside	9-Dec-81	950	Joshua Tree Natl Pk

Table 1. Continued.

Family/Genus	Species	Male	Fem	Imm	County	Date	Elevation (meters)	Locale
Genus #1			1		Riverside	7-Dec-77	unknown	Boyd Desert Center, Coyote Creek
Anapidae								
<i>Gertschanapis</i>	shantzi	3	2	2	Los Angeles	17-Nov-80	1000	Bouquet Reservoir
	shantzi	3	6		Los Angeles	14-Aug-81	1000	Bouquet Cyn nr. SE arm Bouquet Reservoir
Oonopidae								
<i>Oonops</i>	sp. #1		1		Riverside	5-Nov-80	400	Whitewater Cyn
<i>Orchestina</i>	moaba		1		Riverside	13-Feb-77	600	Gavilan Hills
	moaba	1	1		Riverside	25-Dec-80	325	Box Springs Mts nr UCR
	moaba		2		Riverside	29-Nov-81	450	3.2 km S of Valle Vista on Rt 74, under live oak
	moaba	1			Riverside	9-Dec-81	950	Joshua Tree Natl Pk
	moaba	1			Riverside	18-Nov-83	200	Vail Lake
<i>Scaphiella</i>	hespera	1			Riverside	25-Dec-80	325	Box Springs Mts nr UCR
	hespera	1	1		Riverside	9-Dec-81	950	Joshua Tree Natl Pk
Dictynidae								
<i>Dictyna</i>	cholla		1		Riverside	27-Dec-79	400	Whitewater Cyn
	cholla	1			Riverside	25-Dec-80	325	Box Springs Mts nr UCR
<i>Tivyna</i>	moaba		1		Riverside	5-Nov-80	400	Whitewater Cyn
	moaba		1		San Bernardino	25-May-82	550	Twentynine Palms
<i>Yorima</i>	angelica	1			San Bernardino	26-Feb-77	525	E of Mentone
	angelica	1			Riverside	29-Apr-82	325	Clinton Keith Rd, W of Murrieta near entrance to cyn
	imm			1	Los Angeles	17-Nov-80	1000	Bouquet Reservoir
Scytodidae								
<i>Scytodes</i>	undescr. sp.			3	Riverside	13-Nov-79	400	Whitewater Cyn
	undescr. sp.			4	Riverside	5-Nov-80	400	Whitewater Cyn

Table 1. Continued.

Family/Genus	Species	Male	Fem	Imm	County	Date	Elevation (meters)	Locale
Caponiidae								
<i>Orthonops</i>	imm			1	Imperial	25-Mar-80	100	Indian wash, 30 km SE of Glamis
	imm			3	Los Angeles	17-Nov-80	1000	Bouquet Reservoir
	imm			1	Riverside	25-Mar-82	500	Hemet, Motte Reserve
	zebra	1			Riverside	13-Feb-77	600	Gavilan Hills
Corinnidae								
<i>Trachelas</i>	pacificus		2		Riverside	18-Nov-83	200	Vail Lake
	pacificus		1		San Bernardino	28-Sep-83	425	Afton Cyn
	pacificus	1			Santa Barbara	11-Aug-83	1075	Figueroa Mt Rd, 1.6 km W of Rngr Sta
Gnaphosidae								
<i>Herpyllus</i>	propinquus		1		Riverside	17-Feb-78	1100	Bautista Cyn
	propinquus	1			San Diego	13-Mar-81	725	San Felipe @ S2
<i>Micaria</i>	imm			1	Riverside	25-Dec-80	325	Box Springs Mts nr UCR
	pasadena		1		San Bernardino	1-May-85	1100	Summit Vly under cottonwood
Hahniidae								
<i>Hahnia</i>	sanjuanensis		2		Riverside	24-Aug-83	950	El Carrizo Oaks
	sanjuanensis	1	1		San Diego	25-Apr-80	1075	San Felipe
Liocranidae								
<i>Phrurotimpus</i>	mateonus	1	1		Riverside	18-Nov-83	200	Vail Lake
<i>Scotinella</i>	kastoni		1		San Diego	25-Apr-80	1075	San Felipe
Cybaeidae								
<i>Cybaeota</i>	nana		1		Riverside	15-Nov-81	1825	James Reserve Lk Fulmor
	nana		1		Riverside	14-Jan-83	1800	0.8 km E of James Reserve, San Jacinto Mts
Mysmenidae								
<i>Trogloneta</i>	paradoxum			2	Los Angeles	14-Aug-81	1000	Bouquet Cyn nr. SE arm Bouquet Reservoir

Table 1. Continued.

Family/Genus	Species	Male	Fem	Imm	County	Date	Elevation (meters)	Locale
Plectreuridae								
<i>Plectreurys</i>	deserta	1			Riverside	9-Dec-81	950	Joshua Tree Natl Pk
	imm			1	Riverside	22-May-80	275	Corn Springs, SW Desert Ctr
Salticidae								
<i>Neon</i>	pixii	1			Riverside	20-Mar-77	600	Gavilan Hills
<i>Sitticus</i>	dorsatus		1		Riverside	25-Dec-80	325	Box Springs Mts nr UCR
Theridiidae								
<i>Euryopis</i>	spinigera		1		Riverside	9-Dec-81	1350	Joshua Tree Natl Pk, Jumbo Rocks Cmpgrd
	spinigera		1		Riverside	9-Dec-81	950	Joshua Tree Natl Pk
Cyrtoucheniidae								
<i>Aptostichus</i>	imm			1	Riverside	10-Jan-81	325	Riverside
Filistatidae								
<i>Kukulcania</i>	utahana			1	Riverside	10-Jan-81	325	Riverside
Lycosidae								
<i>Pardosa</i>	california	1			San Bernardino	5-Jun-79	950	4.8 km S of Hesperia
Pholcidae								
<i>Psilochorus</i>	acanthus		1		Los Angeles	14-Aug-81	1000	Bouquet Cyn nr. SE arm Bouquet Reservoir
TOTALS		88	206	22				

RESULTS AND DISCUSSION

A total of 316 spiders representing 20 families, 34 genera and 42 species were identified in this study of *Neotoma* midden litter (Table 1). The linyphiid family provided the greatest number of genera (6), species (12) and overall specimens (204), garnering 65.2% of the specimen total. *Tapinocyba dietrichi* Crosby & Bishop (Linyphiidae) was the most frequently collected species, contributing 118 specimens (37.3% of the specimen total). *T. dietrichi* was found in midden debris in five California counties (Los Angeles, Riverside, San Bernardino, San Diego, Santa Barbara), ranging in approximate elevation from 325 to 1825 m but predominantly found at higher elevations. From the 14 middens in which it was found, the average number of *T. dietrichi* per midden was 8.4, with a range of 1–26 specimens. The other *Tapinocyba* species is believed to be undescribed. The linyphiid genus *Spirembolus* contributed four species and the second most commonly collected species, *S. erratus* Millidge (16.5% of specimen total). The amaurobiid genus, *Zanomys*, also contributed four species and the third most prevalent species, *Z. californica* (Banks) (5.1% of specimen total) with one new species to be described as a result of this study.

Although we expected that the linyphiids would comprise the bulk of midden spider inhabitants, we were somewhat surprised to find *Tapinocyba dietrichi* in southern California, let alone its overwhelming contribution to the study's specimen total. To our knowledge, the only other California specimens of this species were taken in Alpine and Alameda Counties in central California (Crosby & Bishop 1933, Boe, unpublished data). This species was not discovered during faunal studies of coastal sage scrub in either San Diego or Riverside Counties (Prentice et al. 1998, 2001) nor has it been found in montane oak (*Quercus* spp.) leaf duff in southern California (Vetter, unpublished data).

Spirembolus erratus was previously known only from samples collected in sycamore litter (Millidge 1980), grass litter in coastal sage scrub and in oak leaf litter (Riverside County) (Prentice & Vetter, unpublished data). In this study, *S. erratus* was collected most often at elevations of 200 to 700 m with two specimens taken near 1100 m. Millidge (1980) states that virtually nothing is known of the natural history of *Spirembolus* species in general, including our other listed *Spirembolus* species, *S. redondo* (Chamberlin & Ivie), *S. hibernus* Millidge, and *S. demonologicus* (Crosby).

Zanomys californica has previously been collected from *Neotoma* middens by J. Linsdale at the Hastings Reserve in central California (specimens at California Academy of Sciences, examined). In our study, *Z. californica* was more prevalent at high elevations (predominantly 1000–1850 m). Leech (1972) records both *Z. californica* and *Z. ochra* Leech (holotype) from dry leaf duff, the latter also taken from a rat midden in Juab County, Utah. *Z. californica* is a common inhabitant of montane oak leaf duff (moist or dry) in southern California (Vetter, unpublished data).

In addition, the concomitant collection of several females of “*Ceratinopsis*” *palomara* Chamberlin along with the male (which is undescribed) in rat nest litter in the San Jacinto Mountains in corroboration with similar recent contemporaneous collections of both sexes in oak leaf duff in the same mountain range (Vetter

& Prentice, unpublished data) lead to the conclusion that this species does not belong in the genus.

Members of many of the spider families identified from our southern Californian pack rat midden study are commonly found within (and possibly restricted to) the leaf litter strata. In several ecosystems, especially those within the desert, *Neotoma* middens represent a drastic vegetative change from the immediate surroundings and may indeed be "oases" of increased survival potential. Occupied middens contain fresh, nocturnally-harvested vegetation and copious amounts of fecal pellets (Vestal 1938, Linsdale & Tevis 1951), both of which may attract and support potential spider prey in the middens. Active and abandoned middens alike provide refugia (for the local inhabitants) that are structurally more stable and offer protection from environmental extremes than many of the other niches within the surrounding environment. Vorhies & Taylor (1945) showed that over a year's time, temperatures inside an Arizona midden were consistently 11 to 17° C lower than soil surface temperatures.

Platnick (1995) states that rat middens may provide a "vestige refuge" for the araneophagous *Orthonops* spp. due to habitat destruction in various regions of southern California. However, in an undisturbed site in the Colorado Desert south of Joshua Tree National Park (400 m elevation), the caponiids *Orthonops icenoglei* Platnick and *Tarsonops* sp. were frequently collected from pitfall traps but not from the remains of a *Neotoma* midden at the site (Vetter, unpublished data). It may be that, in undisturbed areas, caponiids are not restricted to rat middens nor to leaf duff.

Several of the species listed here were previously taken from *Neotoma* middens during various studies. Gertsch (1960) discovered both *Gertschanapis shantzi* (Gertsch) and *Trogloneta paradoxum* Gertsch while Platnick & Forster (1990) recorded only *G. shantzi* during their examination of Linsdale's wood rat material from the Hastings Reserve. Ryckman & Lee (1956) sampled *Neotoma* middens for reduviid bugs (*Triatoma* spp.), primarily in Riverside and San Bernardino Counties and recorded the arachnids found therein. However, for the spiders, they failed to provide frequency data which would have allowed percent species composition comparisons with our study. Species listed in both their study and ours include the following: *Zanomys californica*, *Trachelas pacificus* Chamberlin & Ivie, *Dictyna cholla* Gertsch & Davis, *Herpyllus propinquus* (Keyserling), *Linyphantes laguna* Chamberlin & Ivie, *Pardosa californica* Keyserling, and *Orchestina moaba* Chamberlin & Ivie. Assuming that their determinations were based on mature specimens, the average size of the species sampled was larger than that of the species that we examined which is probably due to sampling differences of whole nests by Ryckman and Lee in comparison to litter under the nests by Cooper.

Vestal (1938) observed general aspects of *Neotoma* and their nests in Berkeley, California and although most of his article focused on *Neotoma* behavior, he did mention some arthropod associates. The only arachnids listed are mites (*Histiostoma* sp.) and a pseudoscorpion (*Apocheiridium fumeroides*). Walters and Roth (1950) sampled 30 nests in Oregon, recording a myriad of arthropod inhabitants, but list only two genera and four families of spiders, *Orchestina* (Oonopidae), *Calymmaria* (Hahniidae), Linyphiidae, and Lycosidae. Linsdale and Tevis (1951) allocated 80 pages of their comprehensive book to animal associates of *Neotoma*

nests at the Hastings Reserve in central California. However, they merely state that “spiders occur everywhere within the house except in the used nest” (“house” meaning the structure and “used” meaning the occupied portion of the structure). Vorhies & Taylor (1940) investigated middens of *N. albigula albigula* in Arizona and found that, within 100 nests, opilionids were the most common arachnid encountered (74% of the nests), followed by miscellaneous spiders (46%), black widow spiders (12%), scorpions (6%) and one tarantula (1%).

In our work here, we have documented the partial diversity of the Araneae in *Neotoma* middens. Members of many of the families that were sampled here are infrequently collected, possibly because of their rarity, secretive habits, and/or very small size. Three of the species on our list are believed to be previously undescribed taxa, one belonging to an undescribed genus in the family Amaurobiidae (D. Ubick, personal communication). To our knowledge, two of the listed linyphiid species, *Ceratinops inflatus* (Emerton) and *Ceratinopsis interventa* Chamberlin, constitute new records for the state of California. Collecting material from underneath wood rat middens should provide a rewarding experience for the interested arachnologist by producing spiders that are rarely seen or that possess bizarre somatic features (such as *Trogloneta* and *Gertschanapis*) and, thus, would be a fruitful challenge.

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We thank K. Cooper for the tremendous effort spent in collecting the *Neotoma* nests, and F. Andrews and S. Frommer for providing information regarding the history of the spiders used in this collection. This project was funded in part by Humbug Mountain Engineering Services P-62 (RSV).

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**REDESCRIPTION OF *GONATOCERUS ATRICLAVUS*
GIRAULT (HYMENOPTERA: MYMARIDAE), WITH
NOTES ON OTHER EGG PARASITOIDS OF
SHARPSHOOTERS (HOMOPTERA: CICADELLIDAE:
PROCONIINI) IN NORTHEASTERN MEXICO**

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Abstract.—The mymarid wasp *Gonatocerus atriclavus* Girault, NEW STATUS, described originally from Trinidad as a variety of *G. triguttatus* Girault, is redescribed and illustrated based on specimens reared from an egg mass of the sharpshooter *Oncometopia clarior* (Walker), collected in Ciudad Victoria, Tamaulipas, Mexico. This is the first known host record for this parasitoid species. Proconiine leafhopper host associations are also reported for three other economically important *Gonatocerus* species from the *ater* species group in North America: *G. ashmeadi* Girault, *G. morrilli* (Howard), and *G. triguttatus* Girault.

Key Words.—Insecta, Cicadellidae, Proconiini, Mymaridae, *Gonatocerus*, egg parasitoid, Mexico.

The glassy-winged sharpshooter, *Homalodisca coagulata* (Say), is native to the southeastern United States and northeastern Mexico. This species recently invaded California and has become established in the southern part of the State. In 2000, several sharpshooter populations were detected north of Kern County. In order to control populations of this xylem-feeding species, an integrated program employing several control options is needed. One cornerstone of an integrated pest management program will be classical biological control.

Egg parasitoids of *H. coagulata* were discovered through survey activities conducted in California and the southeastern United States in 1996 and 1997 (Triapitsyn et al. 1998). Levels of parasitism from one dominant species, *Gonatocerus ashmeadi* Girault (Hymenoptera: Mymaridae), have been high in southern California, but only on the summer and fall generations of the host. The level of parasitism by other local parasitoids, such as *Gonatocerus morrilli* (Howard) and *Ufens* spp. (Hymenoptera: Trichogrammatidae), has been generally very low. It is clear that parasitoids attacking the spring generation of *H. coagulata* need to be imported, screened through quarantine, reared, registered and released through the appropriate permit process, and monitored, in order to impact this pest. Several field expeditions to locate natural enemies of *H. coagulata* and its close relatives were undertaken, including two trips to the Mexican states of Nuevo León and Tamaulipas in early March and April 2000. Preliminary results of these activities were reported by Morgan et al. (2000); this paper provides taxonomic notes on the parasitoid species discovered through our survey and also indicates their host associations, most of which are new records.

Members of the tribe Proconiini (Homoptera: Cicadellidae: Cicadellinae), to which *Homalodisca* Stål belongs, often are referred to as sharpshooters. Distri-

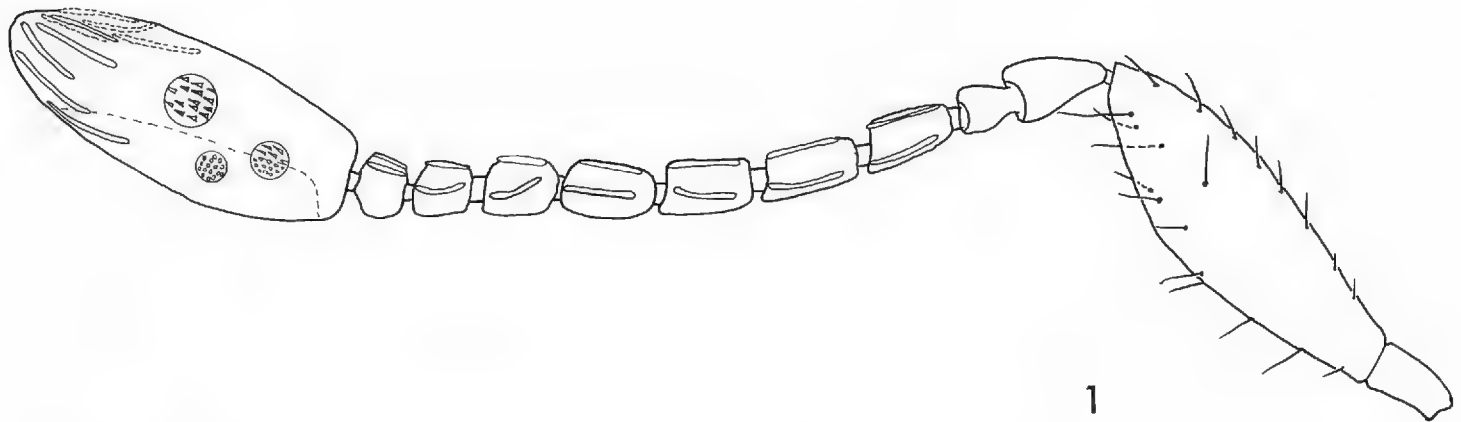


Figure 1. *Gonatocerus atriclavus* Girault. Antenna, female.

bution of the 55 genera and numerous species that comprise this tribe is restricted to the Western Hemisphere (Young 1968); only a few of those occur in the United States, most of them are Neotropical.

In our survey, we searched for egg parasitoids of the species in two sharpshooter genera, *Homalodisca* and *Oncometopia* Stål, based on data obtained during the previous year (Triapitsyn & Phillips 2000). All collections in Mexico were made under a permit issued to our collaborator, E. Ruíz Cancino, Universidad Autónoma de Tamaulipas at Ciudad Victoria. We searched for parasitized sharpshooter egg masses mainly in parks, citrus orchards, and irrigated private gardens. Adult sharpshooters were collected directly in 70% ethanol for further identification and association with the egg masses on their host plants. All parasitized egg masses were sent to the University of California, Riverside (hereafter UCR), quarantine facility under a USDA permit, where emerged parasitoids were screened, identified, and propagated (Morgan et al. 2000).

Investigative responsibilities were divided between authors so that S.V.T. identified mymarid egg parasitoids and worked on taxonomic aspects of this study as well as on conclusive remarks in the "Discussion", L.G.B. coordinated foreign exploration efforts, L.G.B. and S.V.T. collected parasitized egg masses of Proconiini in Mexico, and D.J.W.M. processed and reared the material in quarantine. Terminology for morphological features used in the description is that of Huber (1988); we use the abbreviation F1, F2, etc., to represent the first, second, etc. funicular segments of the females, and the first, second, etc. flagellar segments of the males. Measurements are given in micrometers (μm) as length or, if necessary, as length/width. Abbreviations for depositories of specimens are as follows: CSCA, California State Collection of Arthropods, Sacramento; UATM, Universidad Autónoma de Tamaulipas, Ciudad Victoria, Mexico; UCRC, Entomology Research Museum, University of California, Riverside; USNM, National Museum of Natural History, Washington, D.C.

GONATOCERUS ATRICLAVUS GIRAULT, 1917, NEW STATUS
(Figs. 1–4)

Gonatocerus triguttatus atriclavus Girault, 1917: 19 (as a new variety).

Gonatocerus triguttatus atriclavus Girault; Huber, 1988: 57.

Type Locality.—Mitan, Trinidad.

Types.—Lectotype ♀ on point [USNM], here designated in order to maintain stability of usage of the name, labeled: 1. "Reared from egg-mass of leafhopper";

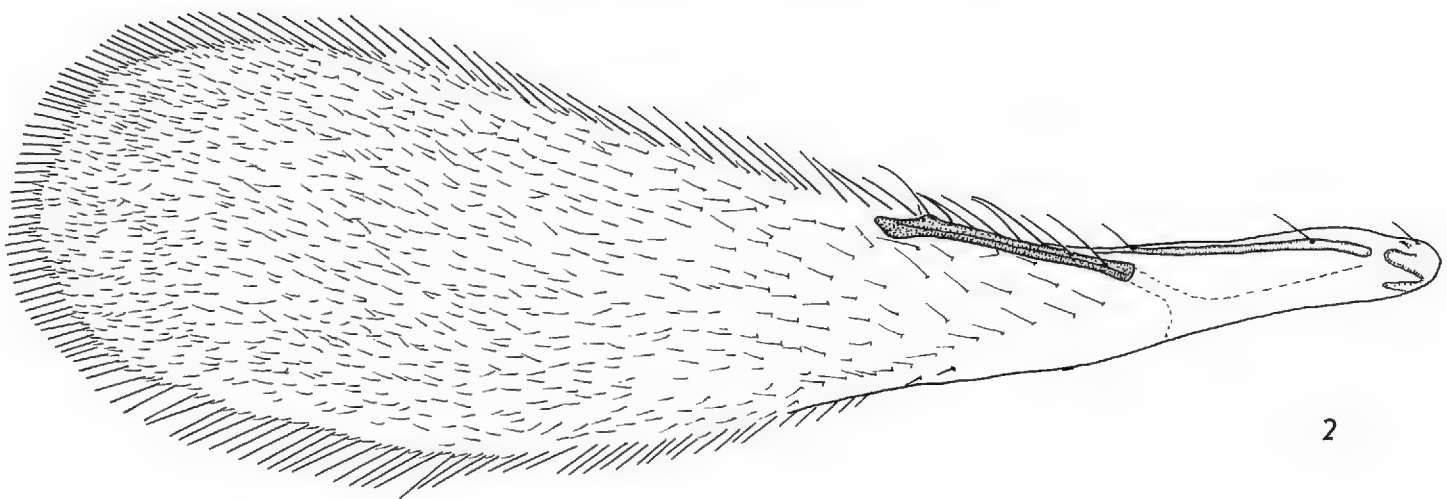


Figure 2. *Gonatocerus atriclavus* Girault. Forewing, female.

2. “Mitan BWI Jan. 1915”; 3. “F. W. Urich Collector”; 4. “53–41”; 5. “*Gonatocerus triguttatus atriclavus* Gir ♂ ♀ types.”; 6. “Type No. 20098 U.S.N.M.”. Girault (1917) described this species as a variety of *Gonatocerus triguttatus* Girault without designating a holotype, from several “types”, Catalogue No. 20098. The type series now consists of the lectotype ♀ mentioned above and 1 ♀ and 1

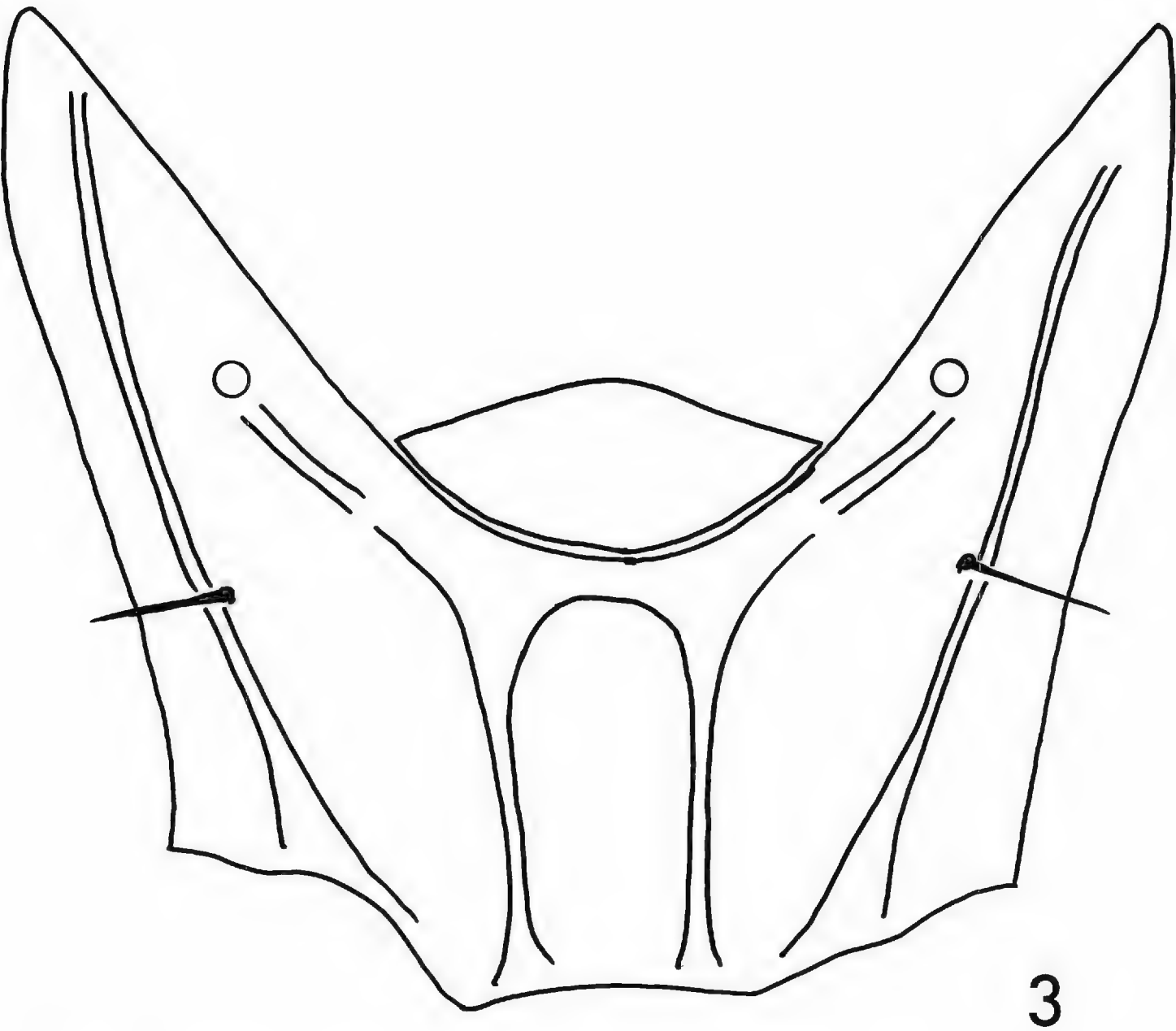


Figure 3. *Gonatocerus atriclavus* Girault. Dorsellum and propodeum, male.

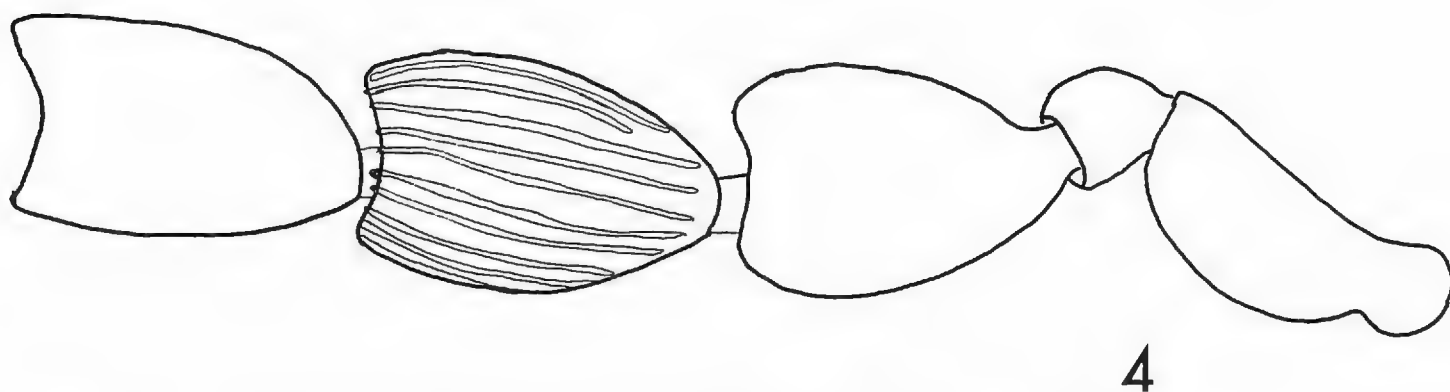


Figure 4. *Gonatocerus atriclavus* Girault. Basal segments of antenna, male.

♂ paralectotypes on points, here designated, labeled same as the lectotype except label 1 is lacking and label 6 with “Paratype” instead of “Type” [USNM].

Other Material Examined.—MEXICO. TAMAULIPAS, Ciudad Victoria, Tamatán, ex. parasitized egg mass of *Oncometopia clarior* (Walker) in hibiscus leaf collected 7 Mar 2000, L. G. Bezark and S. V. Triapitsyn; 2 ♀♀ and 1 ♂ parasitoids emerged at UCR quarantine 20 Mar 2000 [UCRC]. 3 ♀♀ and 1 ♂ labeled: 1. “MEXICO, interc.[epted] S. Antonio, Tex. VI-10-1959 Johnston”; 2. “59-21950 3325 on palm leaves”; 3. “*Gonatocerus triguttatus atriclavus* Girault det. J. T. Huber 1984” [USNM].

Original Description.—The original description is inadequate as it is limited to a single sentence: “Similar to typical form but the antenna concolorous except the club” (Girault 1917). Huber (1988) was first to notice that *G. atriclavus* “is probably a good species, not a subspecies of *triguttatus*”.

Redescription.—*Female.*—*Coloration.* Head pale except upper face and ocellar triangle brown, trabeculae and occiput dark brown, eyes and ocelli dusky. Antenna with scape yellow to light brown; pedicel, F1–F3, F4 (basally) and F7 brown; F4 (distally), F5 and F6 light brown; F8 dark brown; club black. Neck pale, pronotum pale brown with darker spots; mesoscutum orange-brown anteriorly and yellowish posteriorly, parapsidal furrows black; anterior scutellum light brown to brown; axilla brown with darker spot at middle; posterior scutellum yellowish-orange-brown; dorsellum, propodeum, pro-, meso-, and metapleura brown; lateral panels of metanotum and propodeal carinae dark brown. Legs yellowish brown except all tarsi, middle and hind tibiae brown. Wings hyaline; venation brown to dark brown. Petiole dark brown; gaster pale to light yellow with dark brown bands on terga; ovipositor plates brown.

Head: Width 432. Antenna (Fig. 1) with radicle 0.2× as long as scape, scape very long and wide for the species group, 3.0× as long as wide, very finely longitudinally striate (inner side) or almost smooth (outer side), with several rows of strong setae; pedicel short, smooth; F1 short and without sensilla; F2–F5 subequal in length but each slightly wider than preceding article; F6 subquadrate, shorter than F5, F7 slightly wider than long, F8 much wider than long; F2 with 1 or 2 and F3–F8 each with 2 longitudinal sensilla; all funicle segments densely setose; club long (length/width 2.5:1), slightly wider than scape, and about as long as combined length of F1–F4, with 8 longitudinal sensilla, its ventral surface covered with numerous minute, short setae and placoid sensilla, its dorsal surface densely covered with longer setae.

Mesosoma: Pronotum divided medially, each lobe with 1 dorsal and 1 lateral strong seta. Mesoscutum with a pair of strong adnotaular setae. Dorsellum rhomboidal (as in Fig. 3). Propodeal spiracle kidney-shaped; lateral carinae well-developed, submedial carinae almost parallel except anteriorly; propodeum (as in Fig. 3) otherwise smooth. Legs: foretibia with 6–7 conical sensilla. Forewing (Fig. 2) 3.55× as long as wide; marginal cilia very short, longest fringe seta about $\frac{1}{5}$ maximum wing width. Forewing blade bare immediately distal to submarginal vein, with 9 microtrichia behind marginal and stigmal veins, cubital row of setae complete; remainder of blade densely setose. Submarginal vein length 263, with 2 hypochaetae, marginal vein length 216, with 7 microchaetae between proximal and distal macrochaetae, stigmal vein length 58. Hind wing blade bare except for complete rows of microtrichia along margins and several scattered discal setae at apex.

Metasoma: Petiole about as wide as long. Ovipositor about $\frac{3}{4}$ length of gaster, barely exerted beyond its apex. Outer plates of ovipositor each with 1 basal and 1 apical seta.

Measurements ($n = 1$).—*Body:* head: 67; mesosoma: 648; petiole: 72; gaster: 783; ovipositor: 603. *Antenna:* radicle: 66; scape: 329; pedicel: 88; F1: 47; F2: 80; F3: 84; F4: 80; F5: 80; F6: 65; F7: 51;

F8: 43; club: 303. *Forewing*: 1503/423; longest fringe cilia: 88. *Hind wing*: 1107/69; venation: 513; longest fringe cilia: 106. *Legs* (given as coxa, femur, tibia, tarsus): fore: 198, 306, 351, 369; middle: 126, 270, 450, 364; hind: 201, 405, 531, 441.

Male.—*Coloration*: Antenna brown to dark brown except base of scape yellow; face brown; ocellar triangle and occiput dark brown, remainder of vertex and gena light brown; eyes and ocelli pinkish brown. Neck light brown; pronotum, mesoscutum (except light brown edges of lateral lobes), axilla, anterior and posterior scutellum, dorsellum, and propodeum shining brown; mesosomal pleura light brown. All legs light brown except middle tibia and middle and hind tarsi slightly darker, hind tibia brown. Petiole brown, gaster light brown with several dark cross-bands on terga. Otherwise similar to female except for sexually dimorphic characters, as follows: antenna with scape and radicle fused (Fig. 4); basal flagellomeres relatively wide, all flagellomeres with numerous longitudinal sensilla.

Measurements ($n = 1$).—*Total body length* (dry specimen): 1321; *Antenna*: scape + radicle: 153; pedicel: 54; F1: 160; F2: 182; F3: 171; F4: 186; F5: 193; F6: 186; F7: 187; F8: 172; F9: 176; F10: 173; F11: 233. *Forewing*: 1884/532. *Genitalia*: 303.

Diagnosis.—This species is easily distinguished from all other described Nearctic species of the *ater* species group (*ater* subgroup) of *Gonatocerus* that have the forewing with the cubital row of microtrichia complete, extending to base of marginal vein (Huber 1988) (i.e., *G. ashmeadi* Girault, *G. fasciatus* Girault, and *G. triguttatus* Girault) by the transverse F8 in the female antenna. If using the key by Huber (1988), *G. atriclavus* would be separated from *G. fasciatus* by having the forewing hyaline, without fascia, thus keying to couplet 5 together with *G. ashmeadi* and *G. triguttatus*. Besides the shape of F8 mentioned above, *G. atriclavus* can also be easily separated from these two species by the dilated scape, F5 and F6 lighter colored than other funicle segments, and a very long, black club of the female antenna. In both *G. ashmeadi* and *G. triguttatus*, the funicle of the females is uniformly dark brown to black.

Distribution.—Mexico and Trinidad. Although we collected this species in Ciudad Victoria, Tamaulipas, which is near the border between the Nearctic and Neotropical regions, it appears to be a mainly Neotropical species.

Hosts.—The type series was reared from a “leaf-hopper egg mass” in Trinidad (Girault 1917). Our three specimens from Tamaulipas were reared from a sharp-shooter egg mass on a hibiscus plant which was almost certainly laid by *Oncometopia clarior* (Walker).

Upon emergence in quarantine, all the wasps were fed with honey, and the single male was given time to mate with the females. The females were then exposed to freshly laid egg masses of *H. coagulata* in citrus leaves several times; despite the fact that they attempted to parasitize those eggs, we failed to obtain any progeny. Eventually, wasps were killed in 70% ethyl alcohol to serve as voucher specimens.

NOTES ON OTHER EGG PARASITOIDS OF PROCONIINE LEAFHOPPERS IN NORTHEASTERN MEXICO

***Gonatocerus ashmeadi* Girault.** This common North American species was redescribed and illustrated in detail by Huber (1988), who also indicated its known hosts: *Cuerna costalis* (F.), *Homalodisca coagulata*, *H. lacerta* (Fowler), and *Oncometopia orbona* (F.). *Oncometopia clarior* is added here to that list.

Individuals from northeastern Mexico appeared identical to specimens collected in southern California, except for two rearings of darker-colored individuals from Tamaulipas that were not propagated. We attribute such differences in body coloration to intraspecific variability, which is possibly host-induced.

Under quarantine laboratory conditions (22–25° C, 40–50% RH), the Ciudad Victoria population of *G. ashmeadi* successfully parasitized *H. coagulata* eggs laid in a variety of plants including chrysanthemum (*Dendranthema* sp.), crape myrtle (*Lagerstroemia indica* L.), grape (*Vitis vinifera* L.), sweet orange (*Citrus sinensis* (L.) Osbeck), toyon (*Heteromeles arbutifolia* (Aiton) M. Romer), and *Verbascum* sp. Eggs laid by *H. lacerta* in chrysanthemum, crape myrtle, and sweet orange were also accepted for parasitism. Viable offspring emerged from all material tested. Further studies were then conducted on the biology of *G. ashmeadi* as well as of the two other *Gonatocerus* species discussed below; the results will be reported elsewhere.

Material Examined.—*Gonatocerus ashmeadi*: MEXICO: NUEVO LEÓN, Monterrey, UANL campus, ex. parasitized host egg masses coll. 6 Mar 2000, L. G. Bezark and S. V. Triapitsyn, 18 ♀♀, 7 ♂♂ em. 21 Mar 2000 at UCR quarantine (ex. *Oncometopia clarior* (Walker) on leaves of *Fraxinus* sp.). TAMAULIPAS: Ciudad Victoria, 14 Feb 2000, S. N. Myartseva, 16 ♀♀, 2 ♂♂ (ex. sharpshooter eggs on citrus leaf); Ciudad Victoria, Tamatán, ex. parasitized host egg masses coll. 7 Mar 2000, L. G. Bezark and S. V. Triapitsyn, 19 ♀♀, 7 ♂♂ parasitoids em. in UCR quarantine 14–23 Mar 2000 (ex. *Oncometopia clarior* (Walker) on hibiscus leaves); Llera de Canales, ex. parasitized sharpshooter egg mass (on hibiscus leaf) coll. 8 Mar 2000, L. G. Bezark and S. V. Triapitsyn, 1 ♀, 1 ♂ parasitoids em. in UCR quarantine 23 Mar 2000; Municipio Hidalgo, nr. Ejido Benito Juárez, garden in Hotel Hacienda Santa Engracia, ex. parasitized sharpshooter egg mass (on orange leaf) coll. 10 Apr 2000, L. G. Bezark and S. V. Triapitsyn, 7 ♀♀, 3 ♂♂ em. 14 Apr 2000 at UCR quarantine; 5 km N of Valle Hermoso, ex. parasitized host egg masses coll. 13 Apr 2000, L. G. Bezark, 10 ♀♀, 11 ♂♂ em. 20 Apr 2000 at UCR quarantine (ex. *Homalodisca coagulata* (Say) on hibiscus leaves) [UATM, UCRC].

Oncometopia clarior. MEXICO. NUEVO LEÓN: 6 km SE of Allende, Sanatorio Naturista de Canoas, 10 Apr 2000, L. G. Bezark and S. V. Triapitsyn (on citrus); Monterrey, UANL campus, 6 Mar 2000, L. G. Bezark and S. V. Triapitsyn (on crape myrtle). TAMAULIPAS, Ciudad Victoria, Tamatán, 7 Mar 2000, L. G. Bezark and S. V. Triapitsyn (on hibiscus) [CSCA].

***Gonatocerus morrilli* (Howard).** This species is common in southern U.S.A. and Mexico according to Huber (1988). The only previously known host of *G. morrilli*, *H. coagulata*, was first indicated by Turner & Pollard (1959) and later by Triapitsyn et al. (1998). We observed a female of this species ovipositing in a sharpshooter egg mass, probably that of *O. sp. nr. nigricans* (Walker), on a hibiscus plant in the garden of Hotel Rancho Mariposa, near Santander Jiménez in Tamaulipas. Another leafhopper host of *G. morrilli* that we discovered in Tamaulipas is *O. clarior*.

A colony of *G. morrilli*, individuals of which were morphologically similar to those collected in southern California, was established at UCR quarantine using wasps originating from Ciudad Victoria, Tamaulipas. They were successfully reared on both *H. coagulata* and *H. lacerta* eggs laid in host plants as described previously for *G. ashmeadi*.

Material Examined.—MEXICO. TAMAULIPAS: Ciudad Victoria, Tamatán, ex. parasitized host egg mass coll. 7 Mar 2000, L. G. Bezark and S. V. Triapitsyn, 9 ♀♀, 1 ♂ parasitoids em. in UCR quarantine 20–21 Mar 2000 (ex. *Oncometopia clarior* (Walker) on hibiscus leaf); Llera de Canales, ex. parasitized sharpshooter egg masses (on citrus and hibiscus leaves) coll. 8 Mar 2000, L. G. Bezark and S. V. Triapitsyn, 14 ♀♀, 2 ♂♂ parasitoids em. in UCR quarantine 14–23 Mar 2000; same location and collectors, ex. parasitized sharpshooter egg mass (on orange leaf) coll. 11 Apr 2000, 2 ♀♀, 1 ♂ parasitoids em. in UCR quarantine 17 Apr 2000; nr. Santander Jiménez, Hotel Rancho Mariposa, ex. parasitized sharpshooter egg masses (on hibiscus leaves) coll. 9 Mar 2000, L. G. Bezark and S. V. Triapitsyn, 7 ♀♀, 3 ♂♂ parasitoids em. in UCR quarantine 15–20 Mar 2000; same location, 22 Apr

1999, S. Triapitsyn, 2 ♀♀ (on hibiscus, by sweeping); 5 km N of Valle Hermoso, 10 Mar 2000, S. Triapitsyn, 1 ♂ (on hibiscus, by sweeping) [UATM, UCRC].

***Gonatocerus triguttatus* Girault.** This species was redescribed and illustrated by Huber (1988) based on the type series from Trinidad and additional specimens from Texas. Adult specimens of *G. triguttatus* were reared in northern Tamaulipas during April 1999 from the egg masses of its only known host at that time, *H. coagulata*, laid in citrus and peach leaves (Triapitsyn & Phillips 2000). In early spring of 2000, we dissected dead specimens of *G. triguttatus* from an egg mass of a sharpshooter on a citrus (orange) leaf in Gómez Farías, which is in the tropical part of Tamaulipas. These specimens apparently could not emerge from the egg mass and had died not long before we found them. From the same orange tree, we collected an adult male leafhopper, later identified by Raymond J. Gill as *Paraulacizes thunbergi* (Stål); that species thus can be considered as a probable host for *G. triguttatus*. *Paraulacizes thunbergi*, previously known from southern Mexico (Young 1968), is a new addition to the list of proconiine leafhoppers in Tamaulipas that feed and oviposit on citrus plants (Coronado-Blanco et al. 2000). Additional adult specimens of *P. thunbergi* were collected in the Nearctic part of Mexico in Nuevo León and Tamaulipas. Other apparent hosts of *G. triguttatus* are *O. clarior* and *O. sp.* (see “Material examined” below).

A colony of *G. triguttatus* was established at UCR quarantine (Morgan et al. 2000) from adults that emerged from the egg masses of *H. coagulata* in hibiscus near Valle Hermoso, Tamaulipas. This colony was being reared on *H. coagulata* eggs laid in chrysanthemum and orange leaves. All plants tested with *G. ashmeadi* were also accepted by *G. triguttatus*. When *G. triguttatus* females were offered eggs of the smoke-tree sharpshooter, *H. lacerta*, which is native to California, they readily parasitized them and produced viable offspring.

Material Examined.—*Gonatocerus triguttatus*: MEXICO. NUEVO LEÓN, 6 km SE of Allende, Sanatorio Naturista de Canoas, ex. parasitized host egg mass coll. 10 Apr 2000, L. G. Bezark and S. V. Triapitsyn, 1 ♀ em. 14 Apr 2000 in UCR quarantine (ex. *Oncometopia clarior* (Walker) on orange leaf). TAMAULIPAS: Gómez Farías, 8 Mar 2000, S. N. Myartseva, L. G. Bezark and S. V. Triapitsyn, 1 ♀ (dissected from a sharpshooter egg mass on orange leaf); nr. Santander Jiménez, Hotel Rancho Mariposa, ex. parasitized host egg mass coll. 9 Mar 2000, L. G. Bezark and S. V. Triapitsyn, 2 ♀♀ parasitoids em. in UCR quarantine 15 Mar 2000 (ex. *Oncometopia sp.* on hibiscus leaf); 5 km N of Valle Hermoso, 10 Mar 2000, S. Triapitsyn, 1 ♂ (on hibiscus, by sweeping); same location, ex. parasitized host egg masses coll. 13 Apr 2000, L. G. Bezark, 14 ♀♀, 15 ♂♂ em. 20–27 Apr 2000 at UCR quarantine (ex. *Homalodisca coagulata* (Say) on hibiscus leaves) [UATM, UCRC].

Paraulacizes thunbergi.—MEXICO. NUEVO LEÓN, 6 km SE of Allende, Sanatorio Naturista de Canoas, 10 Apr 2000, L. G. Bezark and S. V. Triapitsyn (on *Malva sp.*). TAMAULIPAS: Gómez Farías, 8 Mar 2000, S. N. Myartseva, L. G. Bezark and S. V. Triapitsyn, 1 ♂ (on orange); Municipio Hidalgo, nr. Ejido Benito Juárez, garden in Hotel Hacienda Santa Engracia, 7 Mar 2000, S. N. Myartseva, L. G. Bezark and S. V. Triapitsyn (on *Malva sp.*) [CSCA].

Ufens sp. This species first emerged from a single sharpshooter egg mass laid in an orange leaf collected at Llera de Canales, Tamaulipas. It was later reared in Nuevo León from the eggs of *O. clarior*. It is a gregarious species: 76 wasps emerged from a clutch of 15 sharpshooter eggs (3–7 emergences per host egg). Morphologically, *Ufens sp.* is very similar to, but probably distant from, one taken from unspecified leafhopper eggs on elm and jojoba in southern California; *H. lacerta* is known to be a common associate to the latter plant there. It is also different from the other two *Ufens* species known from *Homalodisca* eggs in

southern California. All species involved are almost certainly undescribed (J. D. Pinto, personal communication).

An attempt was made to initiate a colony of the Mexican *Ufens* sp. at UCR quarantine. In the first generation, wasps were offered egg masses of *H. coagulata* laid in leaves of chrysanthemum (14 egg clutches), toyon (2), grape (2), and orange (6). Wasps emerged from only one clutch, laid in an orange leaf, after 16 days, a longer developmental period than was observed for any of the three *Gonatocerus* species evaluated (D.J.W.M., unpublished data). The second generation was offered host eggs on *Verbascum* sp. (4), crape myrtle (6), orange (17), and chrysanthemum (8). No wasps emerged from these leaves. We suggest that a combination of conditions and strong host plant preferences are responsible for the failure to propagate this trichogrammatid species successfully.

Material Examined.—MEXICO. NUEVO LEÓN, 6 km SE of Allende, Sanatorio Naturista de Canoas, ex. parasitized host egg mass coll. 10 Apr 2000, L. G. Bezark and S. V. Triapitsyn, 37 ♀♀, 6 ♂♂ em. 17 Apr 2000 at UCR quarantine (ex. *Oncometopia clarior* (Walker) on orange leaf). TAMAULIPAS: Llera de Canales, ex. parasitized sharpshooter egg mass collected 8 Mar 2000, L. G. Bezark and S. V. Triapitsyn, 62 ♀♀, 14 ♂♂ parasitoids em. in UCR quarantine 14–15 Mar 2000 [UATM, UCRC].

DISCUSSION

Considering the great diversity of the proconiine leafhoppers, which are among the largest leafhoppers known, and whose eggs are laid in clusters in plant tissue (Young 1968), it is surprising how little is generally known about their biology and natural enemies beyond a few economically important species in the United States. The work by Turner & Pollard (1959) had been practically the only one available on this subject until recently, when the establishment of *H. coagulata* in California prompted the interest in sharpshooter investigations, including studies of their egg parasitoids (Triapitsyn et al. 1998).

Most of the reported egg parasitoids of *Cuerna*, *Homalodisca* and *Oncometopia* species are members of *Gonatocerus*. All known North American species parasitic on these leafhopper genera belong to the *ater* species group of *Gonatocerus* as defined by Huber (1988), and we believe that this might be the case for all proconiines in the New World. The amazing diversity of *ater* group species of *Gonatocerus* in Malaise trap samples from Central and South America correlates very well with the even greater diversity of the sharpshooters from these areas. Further research is needed to demonstrate the validity of this apparent correlation.

It is unlikely that species of the *ater* group of *Gonatocerus* in the New World are species-specific to their leafhopper hosts; rather, they may be narrowly to broadly oligophagous, i.e., able to parasitize species of a number of closely-related host genera within the tribe Proconiini. Some species of parasitoids, however, may display a preference for certain sharpshooter species. Most likely, however, that they discriminate their hosts based on the size of hosts' eggs and the habitat. Some sharpshooter species, like *H. coagulata*, are able to feed upon many plant species, but prefer certain ones for oviposition. To be successful in finding host egg masses, female parasitoids must concentrate their searching activity on those plants. As a result, different parasitoid species may have become more host plant specific than insect host specific, like for instance the common North American mymarid *Anagrus nigriventris* Girault (Al-Wahaibi & Walker 2000). Thus, for a classical biological control program to be successful in California against *H. coa-*

gulata, whose females oviposit on a great number of different plants, introduction of many different species, as well as various biotypes from any given species, may be warranted.

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COPULATION DURATION IN THREE SPECIES OF *ANTHOCORIS* (HETEROPTERA: ANTHOCORIDAE) AT DIFFERENT TEMPERATURES AND EFFECTS ON INSEMINATION AND OVARIAN DEVELOPMENT

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Abstract.—We compared duration of copulation among three species of predatory bugs: *Anthocoris tomentosus* Péricart, *A. whitei* Reuter, and *A. nemoralis* (Fabricius). Copulation duration at room temperatures (22–24° C) was longest in *A. whitei* ($\bar{x}$ = 89.3 min), of intermediate length in *A. tomentosus* ($\bar{x}$ = 40.0 min), and shortest in *A. nemoralis* ($\bar{x}$ = 12.7 min). By interrupting mating pairs we showed that long duration copulations were more likely than short copulations to result in insemination and in ovarian maturation in the female. Probability of ovarian development following a shortened copulation was often lower than probability of insemination, suggesting that insemination alone was not always enough to prompt ovarian development. Size of the sperm reservoir in the female increased with increasing duration of copulation. Males of all species transferred seminal products for most of the copulation period, suggesting that the longer copulations noted for *A. whitei* and *A. tomentosus* (relative to duration in *A. nemoralis*) were not due to post-insemination mate-guarding by *A. whitei* or *A. tomentosus*. Copulation duration was longer at 15° C (range: 25–181 min) than at 25° C (range: 13–102 min). We interrupted mating pairs at both temperatures in all species to determine how the combined factors of temperature and copulation duration affect insemination rates and probability of oocyte maturation. For a given copulation duration, probability of insemination and oocyte maturation were higher at 25° C than at 15° C. Species' differences in copulation duration may reflect differences among species in how rapidly males transfer sperm, and that lower temperatures may make it physically more difficult for the male to force seminal products through the aedeagus.

Key Words.—Insecta, Anthocoridae, mating behavior, sperm transfer, copulation.

Predatory bugs in the genus *Anthocoris* are important sources of biological control in natural and agricultural ecosystems (Lattin 1999). Despite their importance, however, these species are poorly studied in certain aspects of basic biology. Our laboratory has recently begun to study the reproductive biology of several North American species of *Anthocoris*, with goals ultimately to improve our understanding of mating behavior and reproductive biology in these insects.

In the present study, we explored how copulation duration varies among three species of *Anthocoris* that inhabit the Pacific northwest region of the United States: *A. tomentosus* Péricart, *A. whitei* Reuter, and *A. nemoralis* (Fabricius). Copulation duration varies extensively among insect taxa (Thornhill & Alcock 1983), to the extent that even closely related species may exhibit large divergence in this trait (Thornhill & Alcock 1983, Cordero 1990, Lachmann 1997). There are potentially a variety of costs and benefits associated with short- or long-duration couplings (Alcock 1994). Here, we address whether artificially shortened copulations in these species affect probability of insemination, probability of ovarian development, and amount of seminal material transferred to the female. The first hypothesis tested here is that females that experience artificially shortened copulations would be less likely than undisturbed females to be inseminated, as shown in other insect species (Farias et al. 1972, Lew & Ball 1980). We also determined whether these artificially shortened copulations resulted in decreased

probability of ovarian development in the female. Maturation of ovaries in *Anthocoris* requires mating (Anderson 1962, Shimizu 1967). However, it is not known whether the mating act itself is sufficient to prompt ovarian development, or whether insemination is required. If the mating act alone is enough to prompt ovarian development, then we expect that severely shortened copulations, i.e., those resulting in a lack of insemination, would still prompt ovarian development.

Our second major objective was to determine whether the longer copulations of *A. whitei* and *A. tomentosus* (relative to copulation duration in *A. nemoralis* [see below]), was due to mate-guarding by males of these two species. Many insect species prolong copulation beyond that necessary to complete insemination, as a male strategy to delay remating by the female and to ensure paternity (Alcock 1994). Females of *A. tomentosus* and *A. whitei* will mate multiple times under laboratory conditions (unpublished data). Here, we interrupted copulating pairs at several time intervals between intromission and the end of copulation, and estimated quantity of seminal products that had been transferred by the male at each duration. If males prolonged copulation beyond the time required to inseminate the female (i.e., if the male engaged in mate-guarding behavior), we would expect that the amount of seminal material transferred in artificially shortened copulations would not differ from the amount transferred in uninterrupted matings.

Finally, we determined whether temperature mediates the interaction between copulation duration and probability of insemination. In *Anthocoris* spp., sperm are transferred by the male through a thin membranous tube in the female (copulatory tube; Carayon 1953) directly into her sperm pouch. Elsewhere, we suggested that males in certain species of *Anthocoris* experience physical difficulties in forcing seminal materials through the aedeagus and female copulatory tube (Horton et al. 2001). Here, we hypothesized that these difficulties would be amplified with decreasing temperatures, resulting in longer copulations at a lower temperature than a higher temperature. Moreover, we hypothesized that probability of insemination would decrease with decreasing temperature for a copulation of a given duration. This last hypothesis was tested by interrupting mating pairs at specified time intervals for matings conducted at different temperatures.

MATERIALS AND METHODS

Source of Insects.—Laboratory cultures of the three species were begun from field-collected insects. Nymphs and adults of *A. tomentosus* were collected from *Salix* sp. growing west of Tieton, Washington. *Anthocoris whitei* was collected from antelope bitterbrush, *Purshia tridentata* (Pursh), growing in rangeland west of Tieton. Assays with *A. tomentosus* and *A. whitei* were done using offspring of field-collected insects. The third species, *A. nemoralis*, is native to Europe but was released in western North America to control pear psylla, *Cacopsylla pyricola* (Foerster) (McMullen 1971). Nymphs and adults of *A. nemoralis* were collected in Richmond, California from *Acacia longifolia* Willdenow, where it occurs in association with a psyllid pest (Dreistadt and Hagen 1994), and from an unidentified shrub species located in Golden Gate Park, San Francisco. Insects from the two sites were combined into a single culture. Assays used a mix of first-generation (offspring of field-collected insects) and second-generation insects.

Insects were reared on pear seedlings infested with pear psylla at 22° C under long-day conditions (16:8 h [L:D]). Offspring from the parental cultures were

collected as older nymphs and placed singly in glass petri dishes lined with filter paper. Psylla-infested leaves were added daily to each dish. Petri dishes were checked daily for eclosion of new adults. Date of eclosion and sex of each bug were recorded. All assays used previously unmated insects 1 to 6 days of age.

Voucher specimens of each species have been deposited in the M.T. James Entomology Museum at Washington State University, Department of Entomology, Pullman.

Study 1. Copulation Duration, Insemination, and Oocyte Maturation.—Copulation duration was quantified for the interval beginning with intromission and ending with the male's withdrawal of the aedeagus. Withdrawal from the female was always followed immediately by physical separation of the two sexes in all species. Matings were done at room temperature (22–24° C) under fluorescent lighting. Plastic petri dishes (60 mm in diameter) were used as mating arenas. Preliminary trials were conducted to determine copulation duration in pairs allowed to mate without interference. Based upon these trials, we established a range of copulation durations to be tested. Pairs were manually separated after the appropriate time interval by gently prodding the insects with a small paint brush. The test durations are (in min from intromission to manual interruption): *A. tomentosus* (0 [virgin females], 10, 20, 25, 30, 40, and uninterrupted); *A. whitei* (0, 10, 20, 40, 60, 90, and uninterrupted); and *A. nemoralis* (0, 2, 4, 8, 12, and uninterrupted).

Probability of sperm transfer and ovarian maturation were recorded as a function of copulation duration for the manipulated and uninterrupted pairs. Immediately after copulation, females were either dissected to determine whether insemination had occurred, or set aside to allow oocyte development (see below). In *Anthocoris*, sperm are transferred by the male directly into the female's membranous sperm pouch (Carayon 1953); there is no spermatophore. To obtain an indication about the amount of seminal material transferred by the male at different copulation durations, we measured size of the sperm pouch in females allowed to copulate for specified time intervals. After mating, the female was killed by crushing her head and thorax. The abdomen was dissected away from the rest of the body in a drop of saline by using two insect pins. The sperm pouch was carefully removed from the other tissues and submerged in a drop of saline on a microscope slide. The pouch was situated on the slide so that the entrance of the copulatory tube was at the base of the pouch (Fig. 1). The pouch was then measured immediately at 50× under a dissecting microscope equipped with an ocular micrometer. Two measurements were recorded (Fig. 1): maximum length—measured from the base of the membranous pouch to the top of the pouch; maximum width—measured perpendicular to the length measurement. Virgin females were included as controls.

After measuring the pouch, we checked for the presence of sperm by placing a cover slip over the pouch and pressing on the slip until the pouch ruptured. Pouch contents were then examined for the presence of sperm at 100–400× under a compound microscope.

Females that were not dissected were set aside to record whether ovaries matured. Following copulation in both interrupted and uninterrupted pairs, females were separated from the male and put singly on pear seedlings infested with pear psylla. Seedlings and insects were placed in environmental chambers at 22° C and

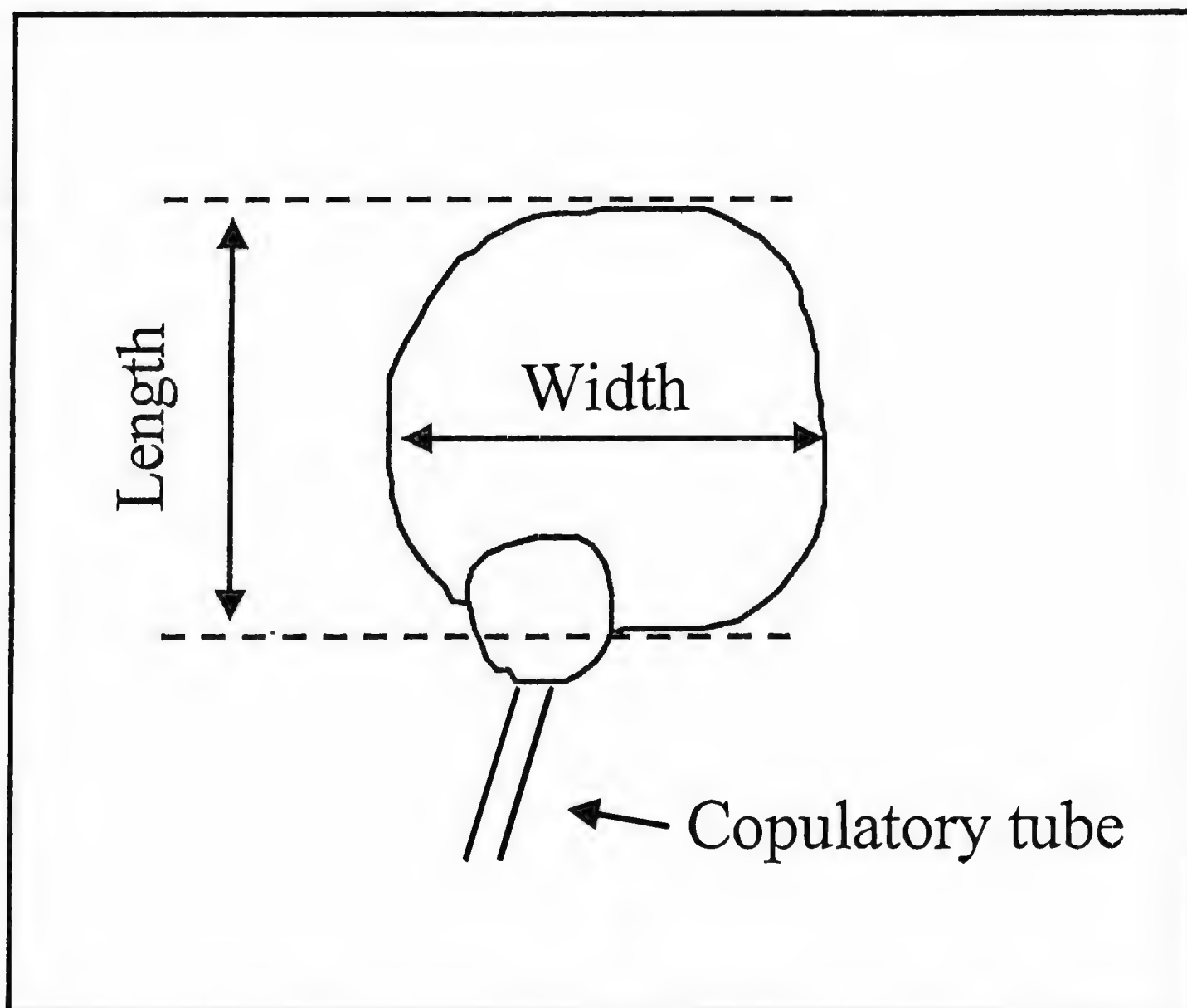


Figure 1. Methods used for estimating maximum length and width of sperm pouch in virgin and mated females of *A. tomentosus*, *A. whitei*, and *A. nemoralis*. Pouch shapes are highly variable both within and between species; illustration provides more-or-less typical shape for *A. tomentosus*.

a 16:8 h photoperiod. Females were then dissected 8–12 (*A. tomentosus*) or 4–6 (*A. nemoralis* and *A. whitei*) days later; the preoviposition period (i.e., the number of days between mating and onset of egg-laying) in these species is ca. 8, 4–5, and 3–4 days in *A. tomentosus*, *A. whitei*, and *A. nemoralis*, respectively (unpublished data). Dissected females were scored as reproductive or as non-reproductive. To be scored as reproductive, the female had to have at least one ovariole containing a mature egg. Appearance of the ovaries is quite different in reproductive and non-reproductive females of these species. The mature terminal oocyte in a reproductive female is approximately 1.5 (*A. nemoralis*), 2.0 (*A. whitei*), and 4.0 (*A. tomentosus*) times as long as the terminal oocyte in an unmated female of the same age (unpublished data), and, moreover, has the characteristic appearance of the deposited egg.

Probability that the female contained at least one mature oocyte was modeled as a logistic function of copulation duration (PROC CATMOD; SAS Institute 1987). We tested whether copulation duration affected probability of insemination using χ^2 tests. To compare frequency of females scored as reproductive to frequency of females that were successfully inseminated, we conducted 2×2 contingency tests. To determine whether size of the sperm pouch depended upon

copulation duration, we first conducted a principal components analysis (PROC PRINCOMP; SAS Institute 1987) on the width and length measures to create a single size variable. Analysis of variance was then used to compare mean principal component scores among different copulation durations. Sample sizes are provided in the RESULTS.

Study 2. Effects of Temperature.—Two temperatures were compared for effects on mating and insemination: 15° C and 25° C. Assays were conducted under fluorescent lighting in controlled environmental rooms set to the appropriate temperature. Petri dishes containing the adult insects were placed in the rooms 1 h before the assay was conducted to allow the insects to acclimate. After 1 h, pairs (1 male and 1 female) were moved to mating arenas (plastic petri dishes 60 mm in diameter) and allowed to mate. Pairs that had not initiated copulation within 30 min of being placed in the arenas were discarded.

Copulation duration was manipulated at both temperatures by separating pairs at two specified time intervals, producing for each species copulations of three durations (in min): *A. tomentosus*—10, 30, and uninterrupted controls; *A. whitei*—20, 40, and uninterrupted controls; *A. nemoralis*—2, 8, and uninterrupted controls. The female from each pair was collected at the end of the mating bout. One-half of the females were then dissected to determine whether insemination had occurred. Females that were not dissected were set aside to monitor ovarian maturation, using the methods described above. Sample sizes are provided in the RESULTS.

Mean copulation duration in uninterrupted pairs was compared between temperatures with a two-sample *t*-test (PROC TTEST; SAS Institute 1987). Contingency tests were used to test whether probability of insemination or probability of oocyte maturation in interrupted matings were affected by temperature and copulation duration. For each species, a $2 \times 2 \times 2$ (temperature [15° C versus 25° C] $\times$ duration [short interrupted versus long interrupted] $\times$ status [inseminated versus not inseminated]) model was fitted to the insemination data and analyzed using log-linear methods (PROC CATMOD; SAS Institute 1987). The analyses were repeated replacing frequency of insemination with frequency of oocyte maturation (i.e., female containing at least one mature oocyte versus no mature oocytes).

RESULTS

Study 1. Copulation Duration, Insemination, and Oocyte Maturation.—Mean copulation duration in uninterrupted pairs differed among the three species (Fig. 2: solid circles having standard error bars). There was also substantial variation within species, as indicated by the range of values noted in uninterrupted pairs: *A. tomentosus*, range = 7–64 min, $\bar{x}$ = 40.0 min, n = 17; *A. whitei*, range = 39–138 min, $\bar{x}$ = 89.3 min, n = 13; *A. nemoralis*, range = 7.7–20.9 min, $\bar{x}$ = 12.7 min, n = 20. Probability of oocyte maturation in females from interrupted pairs increased with increasing duration of copulation (Fig. 2; solid circles and solid lines). Probability of ovarian maturation was 82–100% in uninterrupted females (solid circles with error bars in Fig. 2). In some interrupted females that were scored as reproductive, oocyte maturation was limited to a subset of the ovarioles, rather than in all ovarioles as seen in females from undisturbed matings.

Probability of insemination increased with increasing copulation duration in all

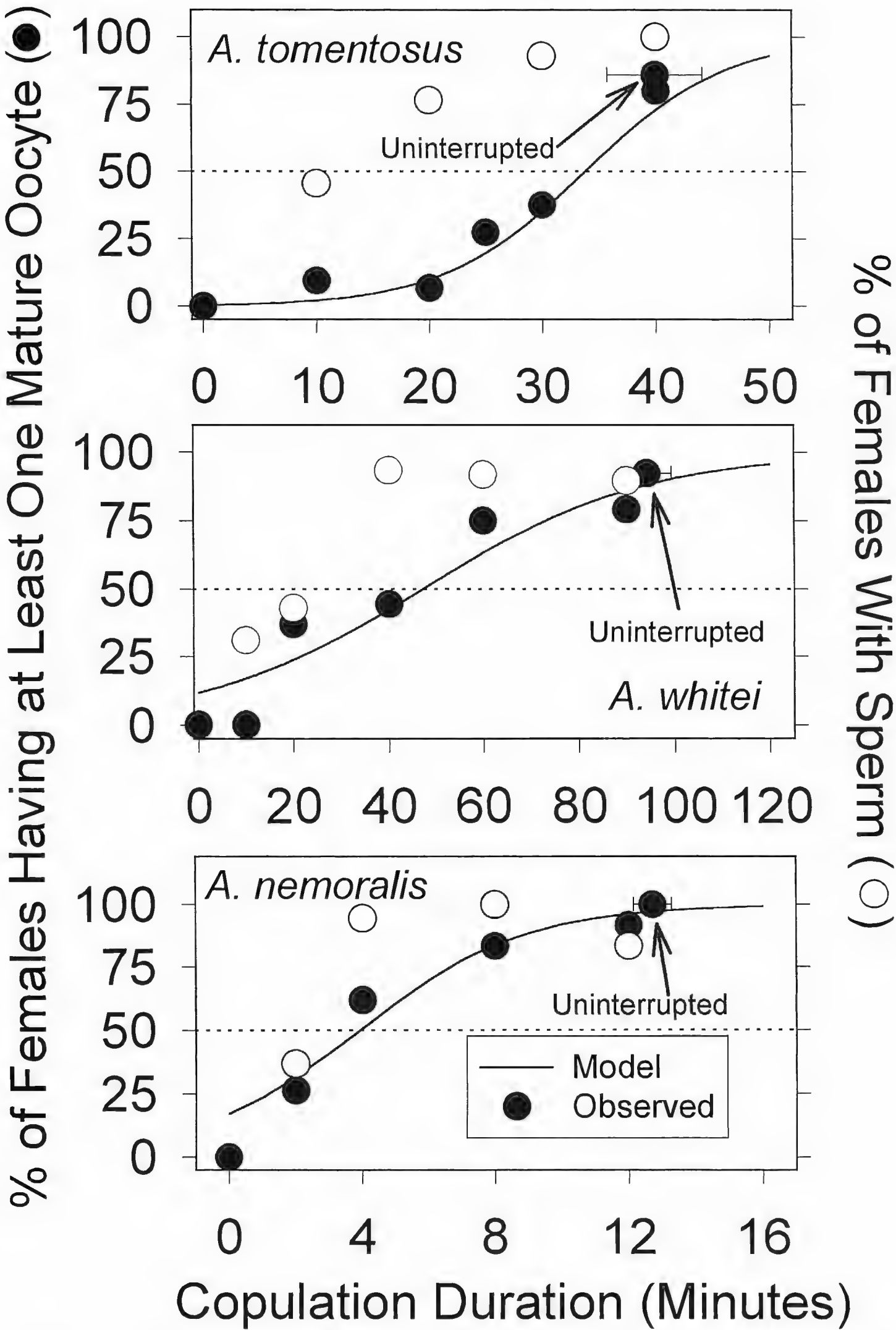


Figure 2. Effects of copulation duration on probability that the female had at least one mature oocyte at dissection (solid circles) and on probability of insemination (open circles; data not collected for *A. tomentosus* at duration = 25 min). Solid circles having standard error bars are results for females

three species (Fig. 2, open circles; by χ^2 tests, $P < 0.01$ in all three species). Percentage of females having sperm was very high in the uninterrupted pairs: *A. tomentosus*, 100% ($n = 12$); *A. whitei*, 91.7% ($n = 12$); *A. nemoralis*, 100% ($n = 17$). Probability of insemination was often higher than probability of oocyte maturation, particularly at the shorter copulation durations (Fig. 2: compare paired open and filled circles), which may indicate that presence of sperm in the female was not always sufficient to prompt oocyte maturation.

Size of the sperm pouch increased linearly with increasing duration of copulation in all three species (Fig. 3; $P < 0.005$ for all three species); quadratic effects were non-significant.

Study 2. Effects of Temperature.—Mean copulation duration in uninterrupted pairs was significantly longer at 15° C than 25° C for all three species (Fig. 4; $P < 0.01$ for all species [by t -tests]). Copulations averaged 79, 32, and 12 min longer at 15° C than 25° C for *A. whitei*, *A. tomentosus*, and *A. nemoralis*, respectively (Fig. 4).

Percentage of females that were inseminated or were characterized as having at least one mature oocyte increased with increasing temperature and duration of copulation (Fig. 5; statistical tests summarized in caption). For *A. tomentosus*, females that were paired at 15° C invariably failed to mature their ovaries if interrupted before finishing copulation (Fig. 5). Uninterrupted copulations tended to result in insemination and oocyte maturation at both temperatures for all three species.

DISCUSSION

While it is apparent that copulation duration is highly variable in the Insecta (Thornhill & Alcock 1983, Eberhard 1996), the significance of this variation is not well understood (Cook 1994, Eberhard 1996). If the function of copulation were no more than a means to deliver sperm to the female, then one would expect selection to favor brevity (Cook 1994, Eberhard 1996). That is, time spent in copulation is not available for other activities, including functions such as feeding, egg-laying, or search for additional mates (Eberhard 1996). However, the fact that copulation in many species occurs for time periods longer than necessary to transfer sperm (Cordero 1990, Alcock 1994) suggests that sperm transfer is not the sole function of copulation. Long-duration copulation may be favored for any of a number of reasons, including as a means to increase certainty of paternity, to

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from uninterrupted pairs. Curves are logistic regressions fitted to ovarian development data, excluding uninterrupted pairs. Regressions are of the form: Prob. of ovarian development = $\exp(\beta_0 + \beta_1[\text{duration}]) / (1 + \exp(\beta_0 + \beta_1[\text{duration}]))$, where β_0 and β_1 are intercept and slope coefficients, respectively. All three regressions indicated that probability of oocyte maturation varied with copulation duration (by χ^2 -tests; $P < 0.01$): $\beta_0 = -5.14$, -2.01 , and -1.58 for *A. tomentosus*, *A. whitei*, and *A. nemoralis*, respectively; $\beta_1 = 0.16$, 0.043 , and 0.40 for *A. tomentosus*, *A. whitei*, and *A. nemoralis*, respectively. χ^2 -tests also indicated that probability of insemination was significantly ($P < 0.05$) higher than probability of ovarian maturation for *A. tomentosus* (at durations of 10, 20, and 30 min), for *A. whitei* (at durations of 10 and 40 min), and for *A. nemoralis* (at duration of 4 min). Sample sizes 12–20 females for each point except for virgin *A. whitei* ($n = 4$).

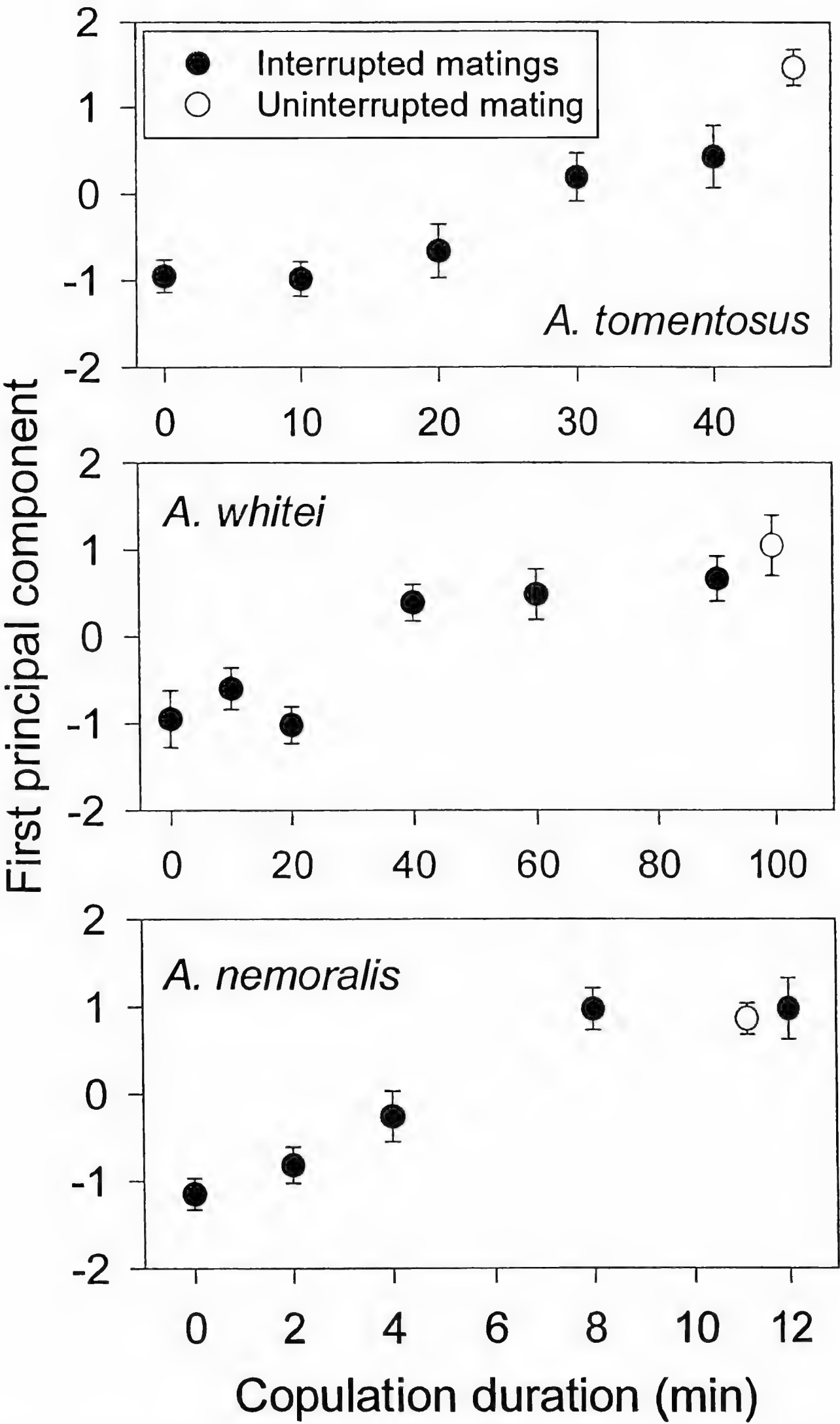


Figure 3. Effects of copulation duration on mean ($\pm$ SEM) sperm pouch size (first principal component obtained from principal components analysis conducted on pouch length and width).

reduce remating opportunities for females, or to transfer nutrients to offspring (see discussions in Alcock 1994, Eberhard 1996).

In the present study, there was a 7-fold difference in mean copulation duration between the species having the shortest mean duration (*A. nemoralis*) and the species having the longest copulation (*A. whitei*). Too little is known about the reproductive biology of *Anthocoris* spp. to do more than speculate about the selective factors that may influence copulation duration in these three species. However, some of the variation among species appears to be due to how rapidly the male was able to transfer sperm and seminal products to the female once intromission had occurred. For example, at 10 minutes following intromission, the percentage of females having sperm in the sperm pouch was approximately 40%, 30%, and > 80% in *A. tomentosus*, *A. whitei*, and *A. nemoralis*, respectively (Fig. 2). To reach the point at which 75% or more of females contained sperm in the sperm pouch required copulation of approximately 4, 20, and 40 min in duration for *A. nemoralis*, *A. tomentosus*, and *A. whitei*, respectively. Moreover, measurements of sperm pouch size suggested that males transferred seminal products for most of the time that the insects were paired. That is, for all 3 species, there was a significant linear increase in sperm pouch size with copulation duration for inseminated females (Fig. 3). This result suggests that the longer copulations of *A. whitei* and *A. tomentosus* relative to duration in *A. nemoralis* were not due to mate-guarding activities by male *A. whitei* and *A. tomentosus*. Instead, species' differences in duration apparently are due to differences in how rapidly males of each species could transfer sperm, or in species' differences in the amount of seminal materials transferred.

By manipulating copulation duration, we showed that shortened copulations had major effects on fitness. Probability of insemination and ovarian maturation decreased with decreasing duration of copulation (Fig. 2), and quantity of seminal material transferred by the male was reduced at the shorter durations (Fig. 3). Other studies have monitored the effects of artificially shortened copulations on fitness measures in insects. In several species, interrupted copulations have been shown to result in reduced probability of insemination (Farias et al. 1972, Lew & Ball 1980, Lachmann 1997), results similar to those reported here. Studies have also shown that longer copulations may result in more sperm being transferred (Yamagishi & Tsubaki 1990). We infer, based upon measurements of sperm pouch size (Fig. 3), that number of sperm transferred to the female by males of *Anthocoris* increased with increasing duration of copulation.

Mating is necessary to prompt oocyte maturation in Anthocoridae, and unmated females in this family deposit few or no eggs (Anderson 1962, Shimizu 1967, Carayon 1970). Almost no research has been done to determine what factors

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Sample sizes are (see also Fig. 2): 9–14 (*A. tomentosus*), 9–12 (*A. nemoralis*), and 12–18 (*A. whitei*). Sample sizes tend to be smaller than those provided in Fig. 2 because damage to the sperm pouch during dissection occasionally prevented measurement of the pouch. Open symbols are results for uninterrupted controls. Effects of copulation duration (by ANOVA; excluding uninterrupted controls): *A. tomentosus* ($F = 5.5$; $df = 4,48$; $P = 0.001$ [linear: $P = 0.004$; quadratic: $P = 0.13$]); *A. whitei* ($F = 8.8$; $df = 5,82$; $P < 0.001$ [linear: $P < 0.001$; quadratic: $P = 0.18$]); *A. nemoralis* ($F = 16.2$; $df = 4,51$; $P < 0.001$ [linear: $P < 0.001$; quadratic: $P = 0.11$]).

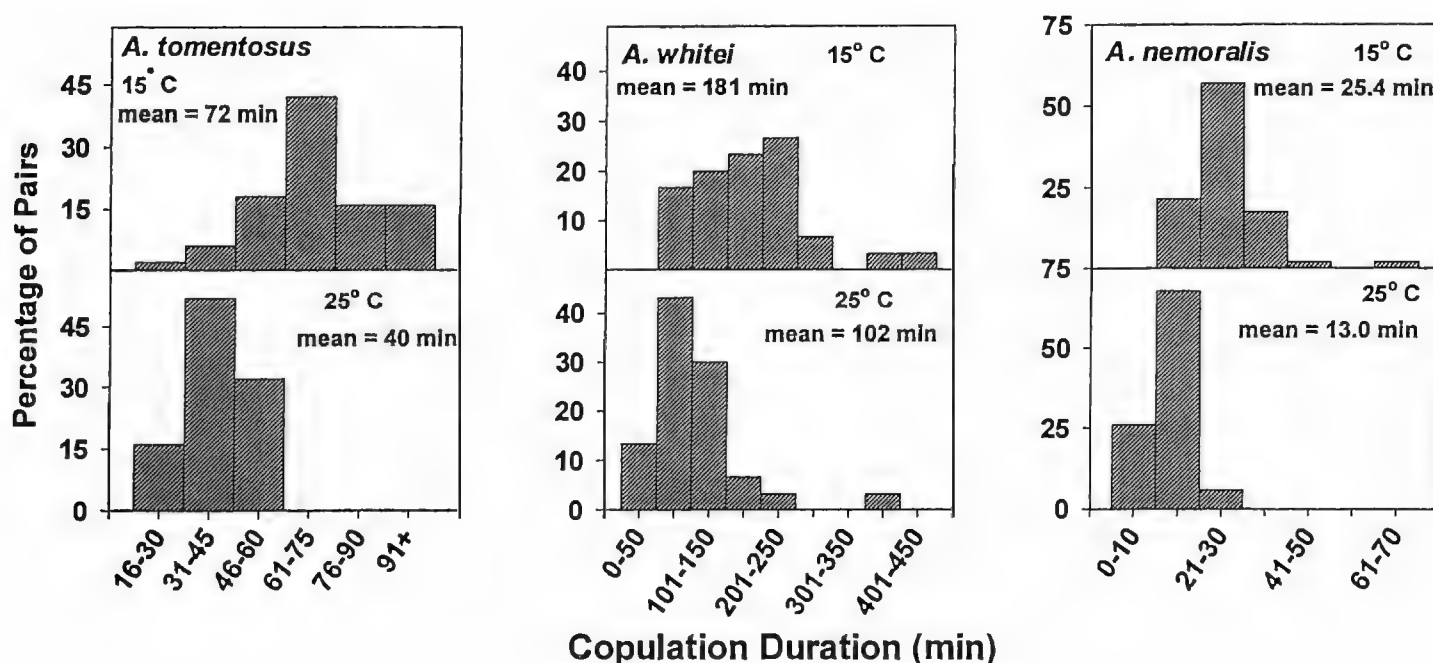


Figure 4. Frequency histograms showing distribution of copulation durations for *A. tomentosus*, *A. whitei*, and *A. nemoralis* mating at two temperatures. Number of pairs per temperature: *A. tomentosus* (50), *A. whitei* (30), and *A. nemoralis* (50).

associated with mating prompt ovarian development in these insects. In the present study, probability of ovarian maturation was often lower than probability of insemination at a given duration of copulation (Fig. 2). This result indicates that intromission alone was not sufficient to prompt ovarian development, and strongly suggests also that insemination was not always enough to lead to oocyte matu-

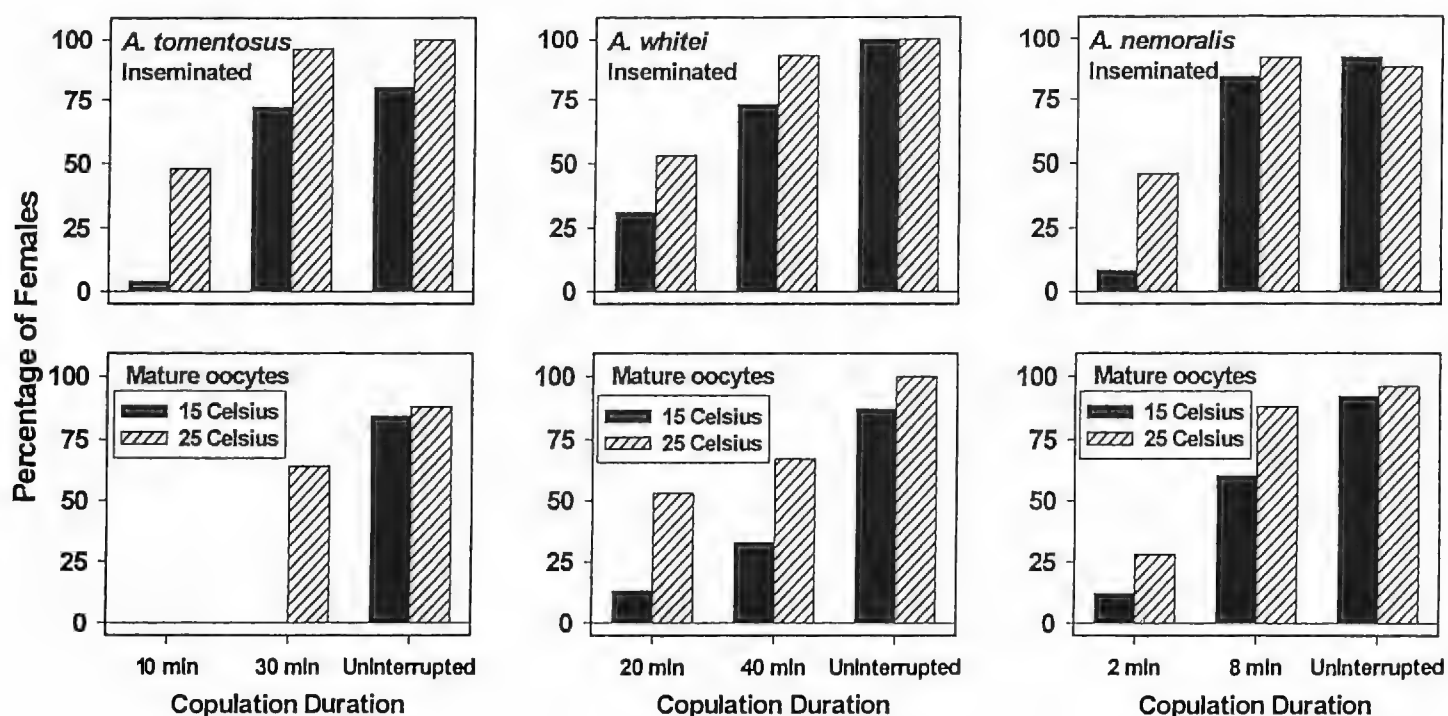


Figure 5. Percentage of dissected females containing sperm (upper panels) or having at least one mature oocyte (bottom panels) as a function of copulation duration and temperature. Missing bars for *A. tomentosus* indicate 0%. Number of females dissected (per bar): *A. tomentosus* (25), *A. whitei* (15), and *A. nemoralis* (25). Insemination: *A. tomentosus* (temperature, $\chi^2 = 12.2$, $P < 0.001$; duration, $\chi^2 = 22.5$, $P < 0.001$); *A. whitei* (temperature, $\chi^2 = 3.4$, $P = 0.066$; duration, $\chi^2 = 10.2$, $P = 0.001$); *A. nemoralis* (temperature, $\chi^2 = 7.5$, $P = 0.006$; duration, $\chi^2 = 28.6$, $P < 0.001$). Mature oocytes: *A. tomentosus* data not analyzed due to 0% values; *A. whitei* (temperature, $\chi^2 = 8.0$, $P = 0.005$; duration, $\chi^2 = 2.0$, $P = 0.16$); *A. nemoralis* (temperature, $\chi^2 = 6.4$, $P = 0.01$; duration, $\chi^2 = 25.3$, $P < 0.001$). Data analyzed as a $2 \times 2 \times 2$ categorical model (analysis excluded uninterrupted controls; thus, duration effects refer to comparison of short and intermediate copulations).

ration. The anthocorid egg lacks a true micropyle, and fertilization of the egg takes place in the ovaries before the chorion is formed (Cobben 1968). Sperm must move from the sperm pouch into a bridge of conductive tissue and then eventually to the base of the ovaries (Carayon 1953). In the phylogenetically related Cimicidae, insemination prompts activation of the corpus allatum, which in turn controls maturation of the eggs in the female (Davis 1964, 1965). Sperm must reach the base of the ovaries to result in activation. Sperm are often visible at the base of the terminal oocyte in newly reproductive *Anthocoris* females (unpublished data), but whether that presence is sufficient by itself to prompt egg development is unknown. Davis (1964) showed that seminal fluid was necessary to prompt migration of sperm to the ovaries in Cimicidae, and it is possible that by interrupting mating pairs of *A. tomentosus*, *A. whitei*, and *A. nemoralis*, that we prevented the male from transferring sufficient amounts of seminal products to prompt sperm migration in many females, even in those females that had been inseminated.

Variation in copulation duration may have both genetic and environmental components (Ward & Simmons 1991, Mühlhäuser et al. 1996). One environmental factor shown to affect copulation duration is temperature (Cook 1994). In this study, copulation duration in *Anthocoris* spp. was substantially longer in pairs mated at 15° C than those mated at 25° C (Fig. 4). Additionally, the magnitude of fitness costs associated with shortened copulations was shown to differ between matings done at the two temperatures. For example, percentage of females that were inseminated following a copulation of short duration (20 min in *A. whitei*, 10 min in *A. tomentosus*, and 2 min in *A. nemoralis*) increased from 31 to 53% (*A. whitei*), from 4 to 48% (*A. tomentosus*), and from 8 to 46% (*A. nemoralis*) if mating was conducted at 25° C rather than 15° C (Fig. 5). In sum, for a copulation of a given duration, probability of insemination and, hence, oocyte maturation increased with increasing temperature.

Why should copulation duration be longer at 15° C than 25° C? The simplest explanation would seem to be that males had physical difficulties inseminating the female at the lower temperature. As noted above, males in the genus *Anthocoris* transfer seminal products to the female's sperm pouch via a thin copulatory tube (Carayon 1953). The aedeagus of the male is fully extended through the female's tube during copulation. At 15° C, it may have been difficult for the male to force seminal products through the aedeagus and copulatory tube. All three species may inhabit geographic areas that experience quite cool temperatures (Kelton 1978), particularly during spring and fall, and it seems almost certain that these insects encounter daytime temperatures similar to the 15° C temperature monitored here. If the insects mate in the field at this temperature, which remains to be determined, then copulation duration in the field could vary substantially within each species even under field conditions.

Finally, results of this study prompt some interesting questions regarding mating activity of these species under field conditions. Our assays indicate that premature termination of copulation in these species had fairly dramatic effects on fitness. External factors that prompt premature break-up of a copulating pair may result in the female failing to mature any eggs from that copulation. Such factors prompting early termination could include the activities of natural enemies, activities of competing males, or decisions by the female to end the copulation (Eber-

hard 1996: 125). It remains to be determined whether any of these factors are important in affecting the mating activities of these species under field conditions.

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***DIAERETUS ESSIGELLAE* (HYMENOPTERA:
BRACONIDAE), A NEW SPECIES PARASITIC ON
ESSIGELLA PINE APHIDS (HOMOPTERA: APHIDIDAE)
FROM CALIFORNIA**

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Abstract.—*Diaeretus essigellae* n.sp., an aphidiine parasitoid reared from *Essigella californica* (Essig) on *Pinus* spp. from California, is described. The new species is distinguished from other Nearctic aphidiines by its reduced fore wing venation and the absence of notauli, propodeal carinae and prongs on the female hypopygium. *Diaeretus essigellae* may be a useful biocontrol agent against *E. californica* in other countries.

Key Words.—Insecta, Hymenoptera, Braconidae, *Diaeretus essigellae*, *Essigella californica*, taxonomy, biocontrol.

In the Essig Museum of Entomology (University of California, Berkeley), the junior author found specimens of an aphidiine species (Hymenoptera: Braconidae) collected from California, which did not appear to match any other Nearctic genera. After consulting with the senior author, we determined that it was a new species very close to the monotypic *Diaeretus leucopterus* (Haliday), a Palearctic species. We later found additional specimens of the new species in the Entomology Research Museum at the University of California, Riverside, determined by C. F. W. Muesebeck as “*Diaeretus* n. sp.”. In this paper, we describe the new species and indicate its potential as a biological control agent.

MATERIALS AND METHODS

Characters and terms follow those in Wharton et al. (1997). Except for two females and one male which were remounted on microscope slides, all specimens were point-mounted and examined through a stereomicroscope; measurements were made with an ocular micrometer. All illustrations were made by the senior author, using a camera lucida.

Depositories.—Type specimens will be deposited in the following institutions: Australian National Insect Collection, CSIRO, Canberra, ACT, Australia (ANIC); Bohart Museum, University of California, Davis, California (UCD); California Academy of Sciences, San Francisco, California (CAS); Entomology Research Museum, University of California, Riverside, California (UCR); Essig Museum of Entomology, University of California, Berkeley, California (EME); National Museum of Natural History, Smithsonian Institution, Washington, D.C. (USNM); The Natural History Museum, London, United Kingdom (BNHM), and the personal collection of P. Starý, Institute of Entomology, Academy of Sciences of the Czech Republic, Branišovská, Czech Republic (PS).

DIAERETUS ESSIGELLAE STARÝ & ZUPARKO, NEW SPECIES

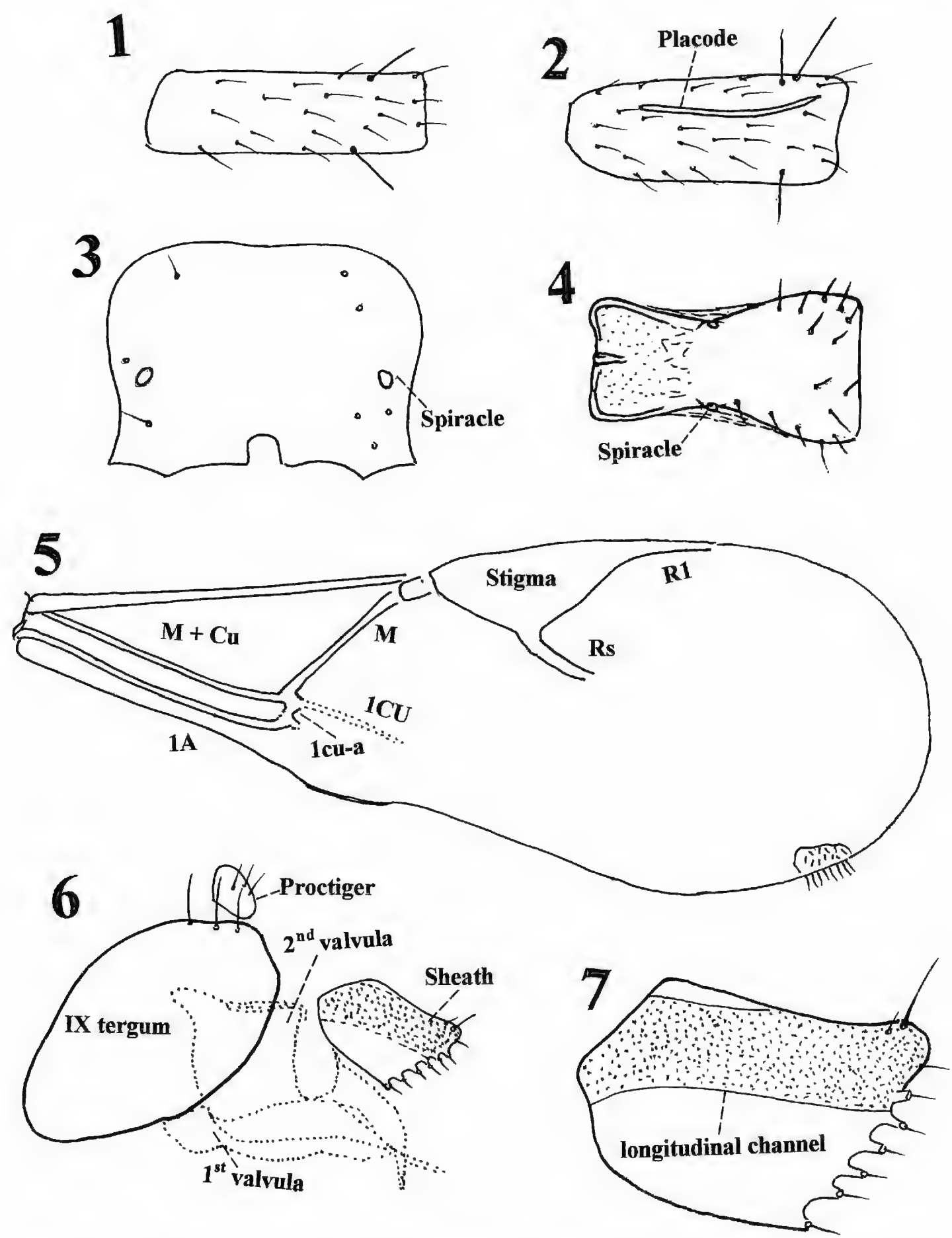
Types.—Holotype, female deposited USNM, data: USA. CALIFORNIA. *RIVERSIDE Co.*, Riverside, 21 Mar 1960, E.I. Schlinger, reared from *Essigella* “*pini*” on *Pinus canariensis*, (60-3-21a). Allotype, male deposited UCR, data: USA. CALIFORNIA. *LOS ANGELES Co.* Lake Hughes, 22 May 1959, E.I. Schlinger, reared from *Essigella* “*pini*” on *Pinus ponderosae*, (59-5-23k). Paratypes: USA. CALIFORNIA. *LOS ANGELES Co.* same data as allotype, 3 females, 1 male. *MARIN Co.* San Rafael, 4 Jun 1991, R.L. Zuparko, foliage of *Tilia* sp., 1 female. *MONO Co.* White Mountains, Crooked Creek Lab., 10,100' elev. 16–21 Aug 1984, R.F. Gill, 1 female. *RIVERSIDE Co.* Lake Hemet, 18 May 1959, E.I. Schlinger, from *Essigella* sp. on *Pinus ponderosae*? (59-5-18b), 1 male; Riverside, 30 Jan – 4 Feb 1925, P. Timberlake, from *Essigella* sp. on pine, 1 female, 2 males; same data as holotype, 35 females, 25 males; 12 Apr 1960, E. I. Schlinger & J. C. Hall, reared from *E. californica* on *P. canariensis* (60-4-12a), 8 females and 3 males; Riverside, California Experiment Station (= U.C. Riverside campus) 3 Mar 1960, E.I. Schlinger, reared from *Essigella* “*pini*” on *Pinus canariensis* (60-3-3a), 5 females, 5 males; same data except 9 Mar 1960 (60-3-9a), 10 females, 9 males, same data except 23 Mar 1960 (60-3-23a), 17 females, 5 males; same data except 27 Mar 1960 (60-3-27a), same data except 30 Mar 1960, E.I. Schlinger & J.C. Hall (60-3-30m), 57 females and 61 males; Riverside, Citrus Experiment Station (= U.C. Riverside campus), F.G. Andrews, 30 Mar 1966, from *Essigella* on *Pinus canariensis* (F66-3-30a), 4 females and 1 male; deposited ANIC, CAS, BNHM, EME, PS, UCD, UCR, USNM.

Description.—*Female*.—Length 1.4–1.9 mm ($n = 134$). Head transverse, smooth, shiny and sparsely haired, slightly wider than thorax at tegulae. Occipital carina distinct and complete. Ocelli form isosceles triangle, ocell-ocular distance about $0.5\times$ eye height, anterior-posterior ocellar distance about $2.0\times$ ocellar width. Eye hairless, oval, slightly convergent ventrally, medium-sized, height $1.2\times$ width. Frons width about $0.5\times$ eye width; temple width about $0.7\times$ eye width; tentorio-ocular line about $0.25\times$ eye width; malar space equal to tentorio-ocular line; intertentorial line $2.0\times$ tentorio-ocular line; genal length about equal width of mandible base. Mandible prominent, bidentate. Maxillary palpus 4 segmented, labial palpus 2 segmented. Antenna inserted about midway up eye height, distance from eye about $1.0\times$ torulus width; 14 segmented, filiform, only slightly thickened to the apex, reaching mid-metasoma; length 1st flagellomere (F1) almost $4.0\times$ width, with numerous short adpressed setae, and sparse semi-erect setae which are about $0.75\times$ F1 width, no placodes (Fig. 1); F2 subequal to F1, 1 placode (Fig. 2); remaining flagellomeres very little wider than F2.

Mesoscutum smooth, shiny, notauli completely effaced, traced with sparse setae on disc, anterior portion almost perpendicular to pronotum. Epicnemial carina present anterior-ventrally on mesopleuron, extending to about $0.5\times$ between mid- and hind coxae. Sternaulus absent. Transscutal articulation deep and smooth. Scutellum smooth and rounded. Propodeum shiny, smooth, sparsely haired, without carinae (Fig. 3).

Fore wing hyaline with reduced venation (Fig. 5): m-cu and r-m completely absent, RS short, not reaching apex of stigma; stigma triangular, length about $3.0\times$ width; R1 length about $0.5\times$ stigma length; Rs short, pigmented section not exceeding apex of stigma; M, M+Cu, 1A and 1cu-a present and pigmented, 1CU only faintly indicated basally. Disc completely covered with setae, somewhat denser distad of M; length of apical-posterior marginal setae about $3.0\times$ length discal setae. Hind wing hyaline with complete basal cell; basal cell bare except few setae anteriorly, remainder of wing uniformly covered with setae; posterior marginal setae about $0.33\times$ wing width at hamuli.

Metasoma lanceolate, length about $1.2\times$ length head and mesosoma. Petiole smooth, shiny with sparse setae laterally on apical half (Fig. 4); almost parallel-sided, but markedly narrowed basad of spiracles, almost $3.0\times$ as long as broad at spiracles; dorsum slightly impressed laterally just posterior to spiracles. Remaining segments smooth, shiny with sparse setae. Genitalia as figured (Fig. 6); ovi-



Figures 1–7. Female *Diaeretus essigellae*. Figure 1. First flagellar segment. Figure 2. Second flagellar segment. Figure 3. Propodeum. Figure 4. Petiole. Figure 5. Forewing. Figure 6. Female genitalia. Figure 7. Ovipositor sheath.

positor sheath spatulate, apical setae with tubiform base, with an internal longitudinal darkened channel (Fig. 7); ovipositor curved down.

Color medium brown; scape yellow, pedicel light brown but yellow ventrally, F1 light brown but with narrow yellow ring basally, remaining segments successively darker towards the apex. Clypeus slightly lighter than rest of face, mandibles and palpi yellow. Legs generally yellow, except: mid- and hind coxa and hind femur distad of trochantellus and all 5th tarsal segments brown; apices of tibiae,

mid-femur and all 4th tarsal segments light brown. Apices of petiole and following segment with slightly lighter areas; terminal metasomal segments slightly darker.

Male.—Length 1.2–1.8 mm ($n = 113$). Generally as female, except: antenna with 15–16 segments, length F1 $2.5\text{--}3.0\times$ width, length F2 $3.0\times$ width; metasomal petiole tends to be slightly more constricted basal of spiracles. Color of antenna and legs generally darker: scape and pedicel light brown, base of F1 yellow, remainder of flagellum dark brown; hind trochanter and trochantellus yellow brown, mid tibia and femur yellow brown except for lighter apices, all tarsal segments (except basitarsi) yellow brown or at least darkly tinged.

Variations.—Out of 108 females with intact antennae, 107 were 14-segmented and one was 15-segmented. Of 81 males with intact antennae, 22 were 15-segmented, and 59 were 16-segmented. Smaller specimens (especially in the males) tended to have a markedly greater constriction basad of the petiole spiracles, thus giving the petiole more of an hourglass shape. Some individuals had a greater degree of darkening on legs. The two individuals from Mono and Marin Counties were markedly darker: body almost black; scape light brown, pedicel dark brown and flagellum almost black; mandibles yellow brown; base of forecoxa, all of mid- and hindcoxae concolorous with body, foretibia slightly darkened, midtibia and femur brown, hindtibia and femur dark brown.

Diagnosis.—The new species is readily separated from all other Nearctic Aphidiinae by the following combination of characters: reduced fore wing venation (m-cu and r-m completely absent, RS short, not reaching apex of stigma), mesonotum without notauli, propodeum without carinae, female hypopygium without prongs. The species keys to couplet 14 in van Achterberg (1997), where *Diaertus* Foerster is separated from *Adialytus* Foerster and *Diaeretiella* Starý. The new species can be separated from *D. leucopterus* by the absence of the propodeal carina, and from *Adialytus* and *Diaeretiella* by the absence of notauli.

Distribution.—Known only from California (Los Angeles, Marin, Mono, Riverside, and Ventura Counties).

Host.—*Essigella californica* (Essig) (Homoptera: Aphididae) on *Pinus canariensis* C. Smith, *Pinus quadrifolia* Parlatores ex. Sudworth, ?*P. ponderosae* Douglas and ?*Pinus radiata* D. Don.

Material Examined.—See Types. Two additional specimens (1 female, 1 male) in the senior author's collection have the data: USA. CALIFORNIA. VENTURA Co. Cuyama Valley, 22 May 1959, E.I. Schlinger, from *Essigella "pini"* on "*Pinus cembroides parryana*".

DISCUSSION

Mackauer & Starý (1967) reported an undescribed *Diaeretus* sp. in western North America, undoubtedly based on the same series of specimens from the Riverside collection which we have used to describe *D. essigellae*. The host of these specimens was recorded to be *Essigella pini* Wilson. However Sorensen (1994) demonstrated that *E. pini* is known only from eastern North America, and that earlier records of this species from western North America refer to any of several other *Essigella* spp. Unfortunately, an examination of the mummies from which the new species emerged could not identify the host aphid more specifically than "*Essigella* sp." (J.T. Sorensen, personal communication). However, one series of specimens (60-4-12a) we examined were correctly labelled as being reared from *E. californica*, and others were from the same collection series (60-3-9a) which were identified as *E. californica* (Essig) by Sorensen (1994), collected on

Pinus canariensis in Riverside. *E. californica* is the most polyphagous species of the genus, and the only *Essigella* species reportedly reared from *P. canariensis* in California (Sorensen 1994).

The two specimens from Ventura County were also recorded from *Essigella* “*pini*”, but on “*P. cembroides parryana* Voss”, which is a synonym for *P. quadrifolia* (Munz & Keck 1968). Sorensen (1994) reported that, other than a single record of *E. fusca voegtlini* Sorensen, the only *Essigella* species recorded from this pine was *E. hoerneri* Gillete & Palmer (known from Ventura County), and specifically noted that *E. californica* was not found on it. *E. californica* and *E. hoerneri* are very closely related, difficult to distinguish from each other, and have overlapping geographical distributions, although they have different favored host plants (Sorensen 1994). We therefore believe it likely that *D. essigellae* will attack both species.

In northern California, parasitized *E. californica* have been noted on *Pinus radiata* (D.L. Dahlsten, personal communication). However, the adult aphidiines responsible have yet to be collected. To date, we have seen only a single *D. essigellae* from northern California (Marin County), with no host records.

Several species have been previously placed within the genus *Diaeretus*, but Starý (1960) determined that it was monotypic, containing only *D. leucopterus*. Based on this, one of the characters used to distinguish the genus was a propodeum with a carinate areola (Starý 1960, 1970; van Achterberg 1997). The absence of this areola in *D. essigella* initially led us to believe that this species represented a new genus. However, in the closely related genus *Pauesia* Quilis Pérez, there is a considerable variation in the completeness of the longitudinal carinae on the propodeum, suggesting that the presence of propodeal carina is of doubtful generic value. We expect many Nearctic aphidiine species still remain to be discovered, leading to possible future nomenclatural changes, and felt it better to adopt a conservative approach and keep the new species in an established genus. It might be added that both *Diaeretus* species attack closely related hosts (in the subtribe Eulachina) in similar ecological niches: *D. leucopterus* is a parasitoid of *Eulachnus* (= *Protolachnus*) spp. on conifers (Mackauer & Starý 1967, Mackauer 1968, Starý 1970), while *D. essigella* attacks *Essigella californica* on *Pinus* spp.

Pinus radiata has been exported throughout the world, with large plantings in Australia, New Zealand, Chile, South Africa and Spain (Ohmart 1981). Recently, *E. californica* has been reported in Spain and France (Tizado & Núñez-Pérez 1996, Turpeau & Remaudière 1990), New Zealand, and as a major pest of *P. radiata* in Australia (Carver & Kent 2000). In contrast, *E. californica* is not considered a pest in California, though some sooty mold is associated with its honeydew production (Burke 1937, Ohmart 1981) and some *Essigella* species occasionally damage Christmas tree plantations (Sorensen 1994). Although the efficacy of *D. essigellae* in suppressing *E. californica* populations has not yet been determined, the relatively innocuous nature of the aphid in California suggests it may be under effective biological control here. If so, *D. essigellae* may prove to be valuable as an importable biocontrol agent.

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Scientific Note

THE IMMIGRANT LEPTOPODID, *PATAPIUS SPINOSUS* (ROSSI), IN OREGON (HEMIPTERA: HETEROPTERA: LEPTOPODIDAE)

Usinger (1941. Bull. Brooklyn Entomol. Soc., 36: 164–165) first reported this non-indigenous species from North America, based on specimens from California. Brothers (1979. Great Basin Nat., 39: 195–196) published on its occurrence in Idaho and Nevada and included a drawing of the adult. Recently, Zack et al. (2001. Pan-Pac. Entomol., 77: 47–50) added Washington as a locality and provided observations on the habitat and habits of this remarkable bug in eastern Washington. The collections of the Oregon Department of Agriculture, Salem, Oregon, contain a specimen of *Patapius spinosus* (Rossi) with the following information on it: OR, Rogue River, 10 III 1959, under pine bark, K. Goeden coll. Also included in their collection are specimens bearing the following information: CA, Glenn Co., Willows, 12 XII 1962, under boards, Haig Dudley coll. Previously, I have seen many specimens from a xeric site in California where specimens were collected beneath the loose bark of a dead, fallen tree—far from any water. Lindskog (1995. pp. 137–140. In Aukema & Rieger (eds.). Cat. Heter. Pal. Reg. 222 pp.) indicated that species of *Patapius* Horváth may be found under the bark of trees well removed from water: species of other genera of Leptopodidae are known to live in habitats much like that of species of Saldidae—close to water. The movement of grape stock in the earlier days of California grape cultivation was a possible source of individuals of this predatory bug. Subsequent movement of grape stock and other vegetative and road building materials (see Zack et al. 2001) likely contributed its further distribution in western North America. It may be expected in other disturbed sites throughout the region.

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Scientific Note

METOPOPLAX DITOMOIDES (COSTA), A SPECIES OF OXYCARENIDAE NEW TO NORTH AMERICA (LYGAEOIDEA: HEMIPTERA: HETEROPTERA)

Metopoplax ditomoides (Costa) is reported for the first time as an established species in the United States. The only other record was its interception in Massachusetts in excelsior in a shipment of goods from Spain (USDA, Plant Pest Contr. Div., Agric. Res. Ser. 1958. Coop. Econ. Ins. Rep., 8(42): 907). This was the sole citation of *M. ditomoides* from North America cited by Slater (1964. Univ. Conn., Storrs, Conn. U.S.A. 778 pp.), and it was not listed from the United States by Ashlock and A. Slater (1988. Cat. Het. pp. 167–245) or by Slater and O'Donnel (1995. N.Y. Entomol. Soc., New York. 410 pp.) Both males and females of this distinctive lygaeoid were beaten from commercially grown hazelnut trees (*Corylus avellana* (L.)) grown on a farm near Monmouth, Oregon during August 1998 by K. Wetherill. These specimens were part of a survey of insects on cultivated and native species of *Corylus* in western Oregon by Wetherill (2000. M.S. Thesis, Oreg. St. Univ., Corvallis. 123 pp.). Only adults were taken on these trees. Additional specimens were brought in for identification in February 2000. These specimens included a specimen recovered from a Lindgren Funnel Trap placed by the Oregon Department of Agriculture at Lowell Road, vicinity Jasper, Lane County, Oregon, 28 July 1999 (ex. J. LaBonte); adult individuals swarming on cars and a mailbox near Corvallis, Benton County, Oregon, 7 February 2000 (ex. L. Royce); hundreds of adults swarming in a farmhouse near Gervais, Marion County, Oregon, 11 February 2000 (ex. D. McGrath) and adults swarming in a home in Amity, Polk County, Oregon, 14 February 2000 (ex. L. Royce). These records indicate the species is now well established in Oregon and likely to be found elsewhere.

Slater (1964) provided a bibliography of *M. ditomoides* from its description in 1843 and the reader is referred to that publication for complete coverage. This species is widespread in parts of southern Europe and northern Africa. The initial specimen found in England was taken at Hounslow Heath, Middlesex, on a "rubbish tip up" (Woodroffe, 1953a. The Entomologist, 86: 34–34a, 1953b. 86: 224–225) suggesting a recent introduction as the fauna of that country has been long known. Woodroffe (1953b) included a drawing of the adult and Southwood and Leston (1959. Land & water bugs of the British Isles. 436 pp.) discussed the species and included an illustration. *Metopoplax ditomoides* resembles species of *Crophius* but is more slender in shape. (See Slater & O'Donnel, 1995, p. 74 for discussion of status of *Crophius*) and see Hoberlandt (1987. Acta Entomol. Mus. Prague, 42: 11–30) about possible synonymy of *Crophius* with *Anomaloptera* Amyot & Serville. The small size (2.8–3.4 mm); swollen, spatulate clypeus; distinctive black head, pronotum, and scutellum, together with the pale, almost white forewings with distinctive dark veins make the recognition easy (Fig. 1.) Woodroffe (1953b) indicated that *Matricaria maritima* (L.) and *M. chamomilla* (L.) were common on the site in England. Both species of plants are known intro-

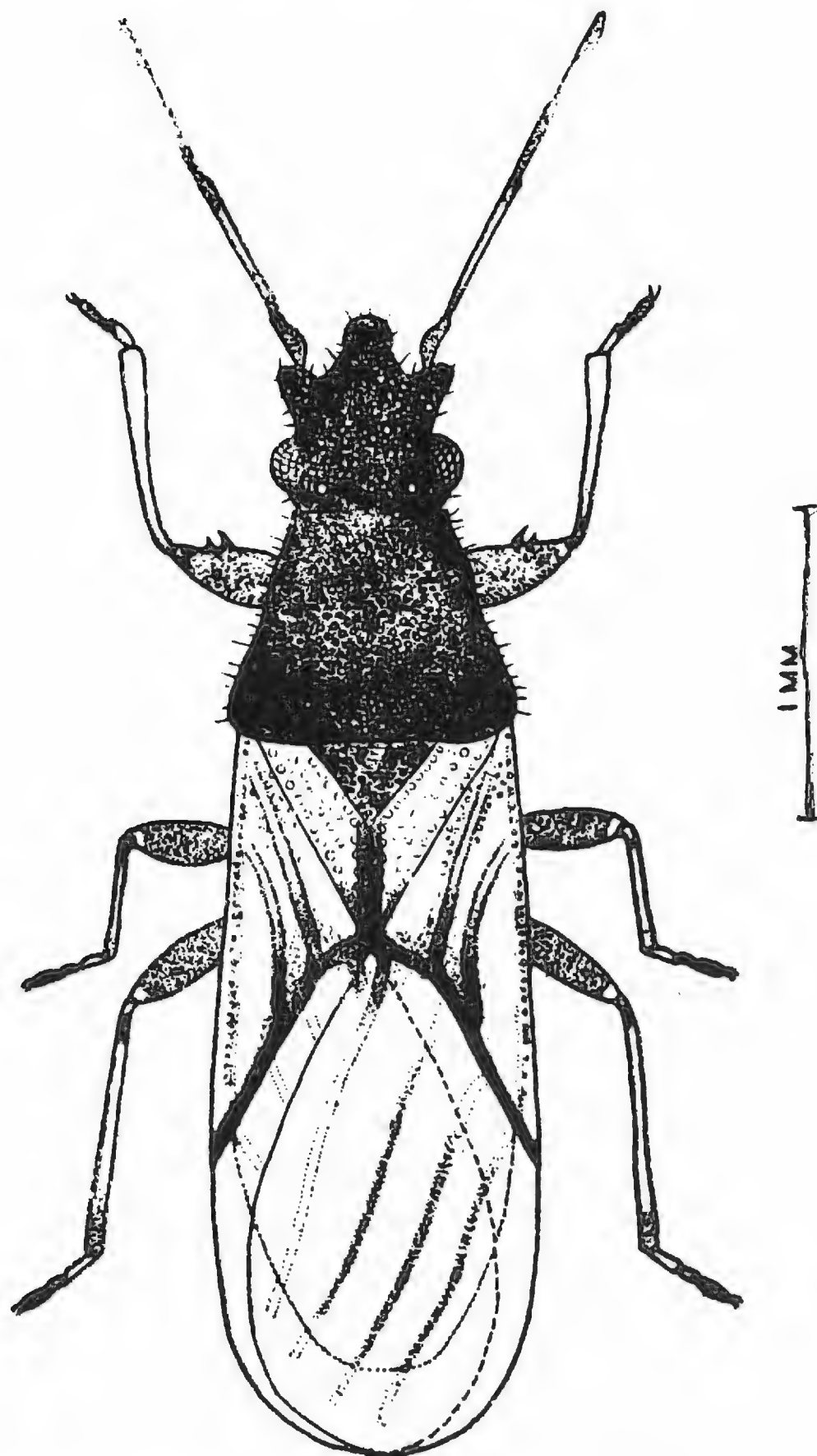


Figure 1. *Metopoplax ditomoides* (Costa) (after Woodroffe, 1953b).

ductions into the Pacific Northwest and are contained in the Oregon State University herbarium from ballast dumps and other localities in Oregon (Scott Sunberg, personal communication, July 1999). This suggests the possibility of a primary host to be a forb with movement onto *Corylus* later in the season. *Metopoplax* Fieber belongs to the Lygaeoidea family Oxycarenidae, a group of seed bugs containing important pests of cotton and other crops (Samy, 1969. Trans. Royal Entomol. Soc. London, 121: 79–165). Knowing this, one should be aware of the possible pest status of *Metopoplax ditomoides*. *Crophius* Stål and *Dycoderus* Uhler are the only native genera of the Oxycarinidae found in the United

States and Canada (Ashlock & A. Slater, 1988). We have taken at least one species of *Crophius* on pine trees in Oregon (J.D.L.), indicating that related taxa also may be found on trees.

The discovery of this insect is a reminder that introductions still occur and may include species of potentially economic importance. Asquith & Lattin (1991. Pan-Pacif. Entomol., 67: 258–271) reviewed the species of Lygaeoidea that had been introduced into the Pacific Northwest when *Metopoplax ditomoides* had not yet been recovered. Wheeler & Stoops (1999. Pan-Pacif. Entomol., 75: 52–54) report *Chilacis typhae* (Perrin) (Lygaeoidea: Artheneidae) from Oregon and Washington. This brings the number of introduced seed bugs in the Pacific Northwest to six. Henry & Adamski (1999. J.N.Y. Entomol. Soc., 90: 275–301) reported on *Rhy-parochromus satunis* (Rossi) (Lygaeoidea: Rhyparochromidae) from California, adding yet another introduced species to the Pacific Coast region.

The Pacific Northwest species of Lygaeoidea may be arranged as follows: Artheneidae: *Chilacis typhae* (Perrin); Oxycarenidae: *Metopoplax ditomoides* (Costa); Rhyparochromidae: *Plinthisus brevipennis* (Latreille); *Megalonotus sabulicola* (Thomas); *Stygnocoris rusticus* (Fallén), and *Stygnocoris sabulosus* (Schilling) (Henry. 1997. Ann. Entomol. Soc. Amer., 90: 271–301). Specimens of *M. ditomoides* have been deposited at Oregon State University and at the Oregon Department of Agriculture, Salem.

Acknowledgment.—We thank the Oregon Filbert Commission for support of this project; M.T. AliNiazee for interest and guidance of the larger project; S. Sunberg for helpful information on introduced plants now found in Oregon; to D. McGrath, J. LaBonte, and L. Royce who provided additional specimens of this bug from Oregon localities; two reviewers for their efforts and comments; and L. Parks for assistance in the preparation of this paper.

This scientific note is dedicated to my long-time friend and colleague, Dr. James A. Slater, whose extensive scientific efforts on the Lygaeoidea have provided us with a superb foundation of all future work on this major taxon.

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Scientific Note

NEW HOST PLANT AND DISTRIBUTIONAL RECORDS FOR SOME *EBURIA* LEPELETIER & AUDINET-SERVILLE (COLEOPTERA: CERAMBYCIDAE) IN NORTH AMERICA INCLUDING MEXICO

Cerambycids of the genus *Eburia* Lepeletier & Audinet-Serville are most in evidence in the American tropics (Monné, M. A. 1993. Catalogue of the Cerambycidae (Coleoptera) of the Western Hemisphere, Part II. Soc. Brasil. Entomol., São Paulo, Brasil). Only 10% of nominal *Eburia* species occur in the Nearctic region, where they breed in trees belonging to several angiosperm families (Linsley, E. G. & J. A. Chemsak. 1997. The Cerambycidae of North America, Part VIII. Univ. Calif. Publ. Entomol., 117). This note provides unknown or unpublished larval hosts and distributional records for 4 species of *Eburia* from the southern United States and Mexico. Data come from field studies in southeastern Texas and specimens in the TAMU collection. Plant nomenclature follows S. D. Jones et al. (1997. Vascular plants of Texas. Univ. Texas Press, Austin, Texas); collection codens follow R. H. Arnett, Jr. et al. (1993. The insect and spider collections of the world (2nd ed.). Sandhill Crane Press, Gainesville, Florida).

Eburia haldemani LeConte. One female was reared from *Ulmus crassifolia* Nuttall (Ulmaceae): TEXAS. GUADALUPE Co.: 10 km E of Seguin, 9 Jun 1988 (TAMU). G. B. Vogt (1949. Pan-Pacif. Entomol., 25: 137–144) recorded this tree as a putative larval host for *E. haldemani*. E. G. Linsley and J. A. Chemsak (1997) list *E. haldemani* as feeding in *Morus* sp. (Moraceae) and *Celtis* sp. (Ulmaceae).

Eburia linsleyi Lacey. Several adults were collected in ARIZONA. GRAHAM Co.: Turkey Creek, 22 Jun 1976, S. McCleve (TAMU), and NEW MEXICO. HIDALGO Co.: Indian Creek, Animas Mts, 1737 m, 5–6 Aug 1976, S. McCleve (TAMU); Godfrey Place, Animas Mts, 1706 m, 7 Jul 1980, S. & J. Dobrott (TAMU). These localities represent the easternmost records for the known distribution of *E. linsleyi* (Monné 1993).

Eburia mutica LeConte. Adults of this Tamaulipan species were taken from beneath loose bark and one eclosed from a pupa cut from dead trunk of young *Acer negundo* L. var. *negundo* (Aceraceae): TEXAS. HARRIS Co.: 29.76° N, 95.44° W, 29 Jul 2000, P. Szafranski, ♀ (MCZC). One male specimen of *E. mutica* was also reared from *Celtis lindheimeri* Engelmann ex K. Koch: TEXAS. HIDALGO Co.: Bentsen-Rio Grande Valley State Park, 11–17 Jun 1977, R. Turnbow (TAMU). Previously, *E. mutica* has been found developing in *Havardia* sp., *Leucaena* sp., *Prosopis* sp., *Sesbania* sp., *Sophora* sp. (Fabaceae), *Citrus* spp., *Zanthoxylum* sp. (Rutaceae), *Celtis laevigata* Willdenow and *Ulmus* sp. (Ulmaceae) (Linsley & Chemsak 1997). The locality of *E. mutica*-*A. negundo* association marks the northeastern range of *E. mutica* (Fig. 1) and the southwestern edge of the continuous, natural range of *A. negundo*. Other records that determine the northern range of *E. mutica* include: TEXAS. BRAZOS Co.: College Station, Jun 1937 & 7 Jun 1977, J. R. Ables (TAMU); GALVESTON Co.: Dickinson, 21 May

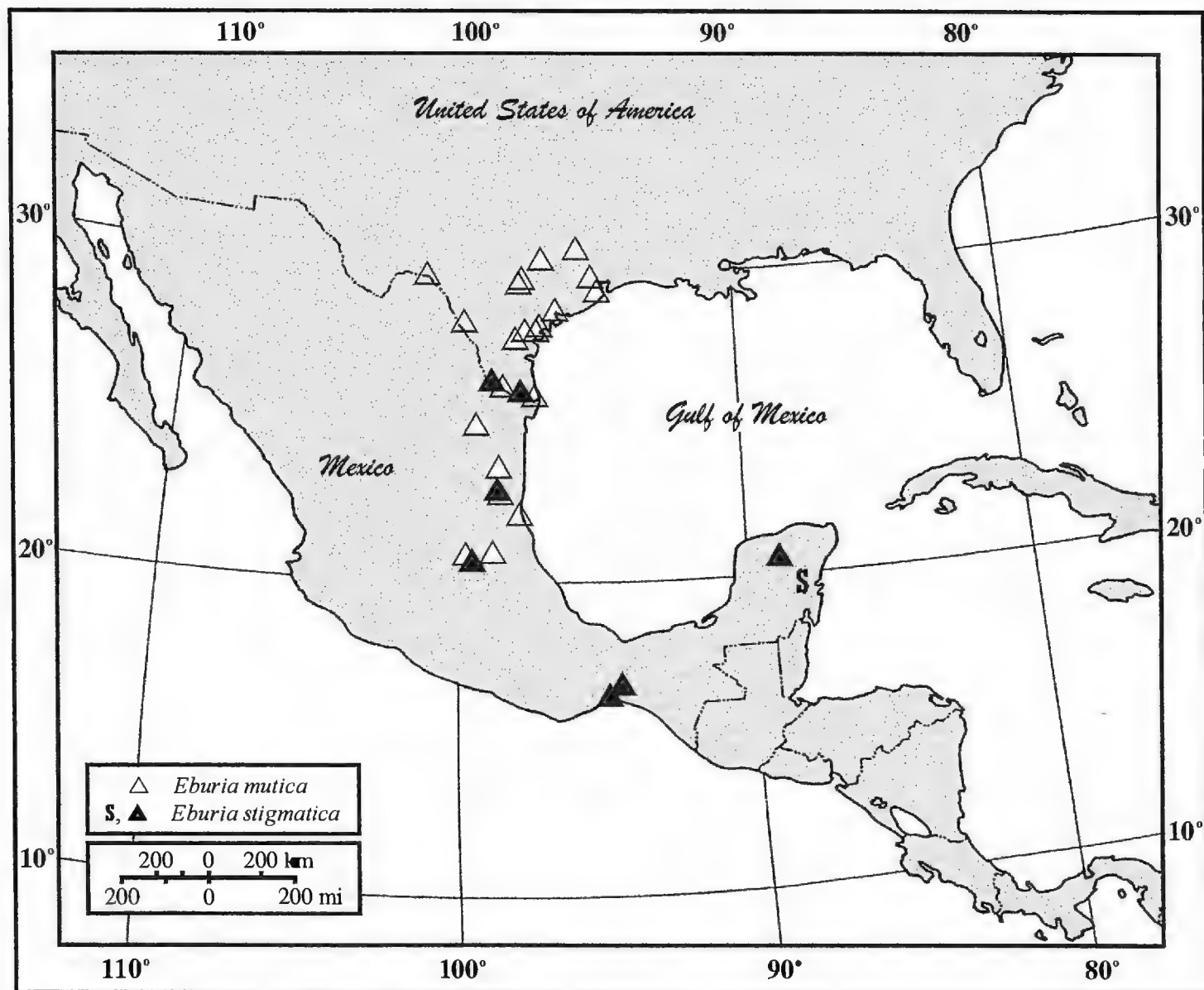


Figure 1. Updated geographical distribution of *Eburia mutica* (open triangles) and *E. stigmatica* (filled triangles, S—state record). Lower Rio Grande valley symbols represent several nearby locales.

& 27 Jun 1932, J. N. Roney (TAMU); TRAVIS Co.: Austin, Jul 1923 (TAMU); VAL VERDE Co.: Langtry, 21 Jun 1990, E. Riley & C. Wolfe (TAMU).

Eburia stigmatica Chevrolat. A female specimen was chopped from *Chloroleucon ebano* (Berlandier) Rico (= *Pithecellobium flexicaule* (Benth) Coulter) (Fabaceae): TEXAS. CAMERON Co.: 5 km SW of Olmito, 24 May 1994, D. J. Heffern (TAMU). *C. laevigata* is the only other known host of *E. stigmatica* (Linsley & Chemsak 1997). This subtropical species was also collected at several localities that extend its range from the lower Rio Grande valley, Texas and northeastern Mexico (Monné 1993) to the Pacific coast of southern Mexico and southeastwards through Yucatan peninsula (Fig. 1): MEXICO. OAXACA: 19.3 km W of Jalapa del Marques, 12 Jul 1971, Clark et al. (TAMU); 16.7 km N of Niltepec, 15 Jul 1971, Clark et al. (TAMU). QUINTANA ROO: Apr 1963 (TAMU). YUCATÁN: Chichen-Itzá, 19 Aug 1965, N. J. Dickey (TAMU); same data except 10–11 Jun 1983, E. Riley (TAMU).

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- Ferrari, J. A. & K. S. Rai. 1989. Phenotypic correlates of genome size variation in *Aedes albopictus*. *Evolution*, 42: 895–899.
- Sorensen, J. T. (in press). Three new species of *Essigella* (Homoptera: Aphididae). *Pan-Pacif. Entomol.*

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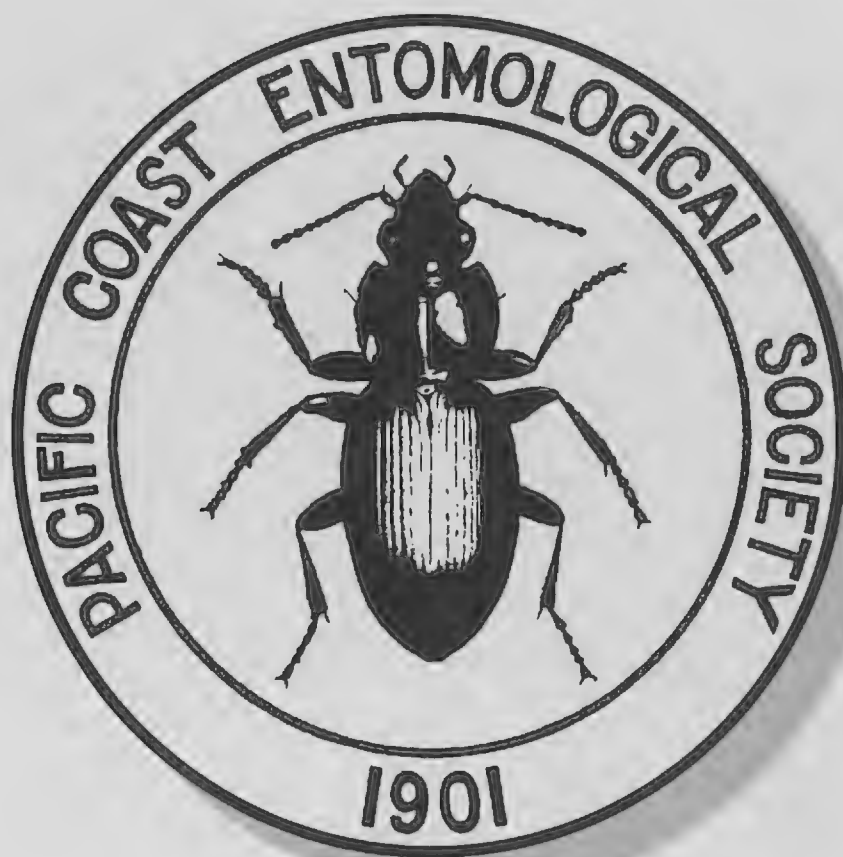
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A NEW SPECIES OF *FOLSOMIA* (COLLEMBOLA: ISOTOMIDAE) FROM BRAZIL, WITH NOTES ON FOIL-SETAE IN THE *FIMETARIA* GROUP

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Abstract.—*Folsomia wellingdae* Potapov & Culik, NEW SPECIES belongs to the *fimetaria* group being close to *F. fimetaria* (Linnaeus), *F. kerni* Gisin, *F. stella* Christiansen & Tucker, and their allies. This new species differs by having two “corner” sensilla on the mesothorax and a well differentiated group of foil-setae on the last abdominal segment. The latter character is of importance in the taxonomy of this group of species.

Key Words.—Insecta, Collembola, Isotomidae, *Folsomia*, *fimetaria* group, foil-setae, Brazil.

Knowledge of the occurrence and ecology of Collembola is lacking, especially in Neotropical and agricultural environments (Mari Mutt & Bellinger 1990, Crosley et al. 1992). Therefore, a project to study Collembola of agricultural soils in Espírito Santo, Brazil, was initiated in 1999 (Culik et al. 2000). During this research a new species of *Folsomia* was found which is described here.

FOLSOMIA WELLINGDAE POTAPOV & CULIK, NEW SPECIES

Types.—Holotype, female; data: BRAZIL. *ESPÍRITO SANTO*: Domingos Martins Municipality, 20°23' S, 41°03' W, 4 Jul 2000, M. Culik, ex. soil, Latossolo, Site B, approximately 950 m el; deposited: Museu de Zoologia da Universidade de São Paulo (MZUSP), São Paulo. Paratypes, 2 females; data: same as holotype; deposited: Moscow State Pedagogical University (MSPU), Moscow. 1 juvenile; data: same as holotype except Site A, approximately 1010 m el; deposited: Museu de Zoologia da Universidade de São Paulo (MZUSP), São Paulo. 2 females; data: same as holotype except collected 21 Dec 1999, Site C, ex. soil, Aluvial; deposited: Universidade Federal do Espírito Santo (UFES), Vitória.

Description.—Body length up to 1.2 mm. Pigment and ommatidia absent. PAO elliptical, about as long as Ant. I width, and 1.5× length of inner edge of unguis III, with a weak constriction and no inner “denticles” (Fig. 3). Maxillary palp bifurcate, outer maxillary lobe with 4 sublobal hairs. Labral formula 4/554. Ventral side of head with 4+4 postlabial setae. Labium as common for the genus, with 4 basomedial and 3 proximal setae, and 16 guards. Ant. I with 2 small basal microsensilla, dorsal and ventral, and 2–3 sensilla (Fig. 3); Ant. II with 3 basal microsensilla and 1 sensillum; Ant. III with 4 common and a single lateral sensillum, without microsensilla; Ant. IV without strongly broadened sensilla. Sensilla on body long, setae-like, little different from common setae. Sensillar formula for Th. II—Abd. V: 4,4/2,2,2,3,5 (s), 1,0/1,0,0,0,0 (ms). On Th. II—Abd. IV, medial sensilla situated in p-row (Fig. 4). Lateral abdominal sensilla blunt or clavate, especially on last two abdominal segments (Fig. 5). Abd. V with 5+5 sensilla, anterior and lateroventral sensilla shorter (Fig. 7). Macrosetae 1,1/3,3,3,4 in number, acuminate and weakly serrate (Fig. 5). Medial macrosetae on Abd. V 3–4× length of mucro. Abd. VI with a group of 14 foil-setae, two of which are unpaired. Foil-seta fl thicker and

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longer (Figs. 5, 7, 10), $0.7-0.9\times$ length of medial macroseta of Abd. V. Axial setae (of one side): 10, $8/4$, 4, 4. Th. III with 14–16 setae in p-row (sensilla not counted). No ventral setae on thorax. Unguis with inner tooth, no lateral teeth. Retinaculum with 4+4 teeth and one seta on corpus. Ventral tube with 4–6+4–6 latero-distal and 5 posterior setae. Anterior furcal subcoxa with 14–16, posterior with 6 setae. Anterior side of manubrium with 3–5+3–5 setae arranged in two irregular longitudinal lines, an apical pair of setae longest, some of the proximal setae very close to medial line (Figs. 1, 2). Manubrium on posterior side with 5+5 latero-basal, 6+6 central, 3+3 distal, and 1+1 apical setae. Lateral sides of manubrium with 2+2 setae. Dens with 20–22 anterior setae and 5(–6) posterior setae (3 basal, 2 medial, and usually, a sixth, minute, seta near the mucro can be observed) (Fig. 1). Mucro bidentate. Ratio manubrium:dens:mucro = 4–5:8–9:1.

Diagnosis.—*Folsomia wellingdae* differs from other *Folsomia* species in having two “corner” sensilla on each side of the mesothorax, and Abd. VI with a group of 14 foil-setae, one pair of which is longer than the others.

Distribution.—Known only from three field sites located within approximately 1000 m of each other at the Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural—INCAPER Centro Regional Desenvolvimento Rural—Centro Serrano (CRDR-CS), Domingos Martins Municipality, Espírito Santo, Brazil. *Folsomia wellingdae* was found in relatively low numbers compared to other (dominant) Collembola species present (unpublished data) but in a variety of soil conditions and is thus likely to be more widely distributed.

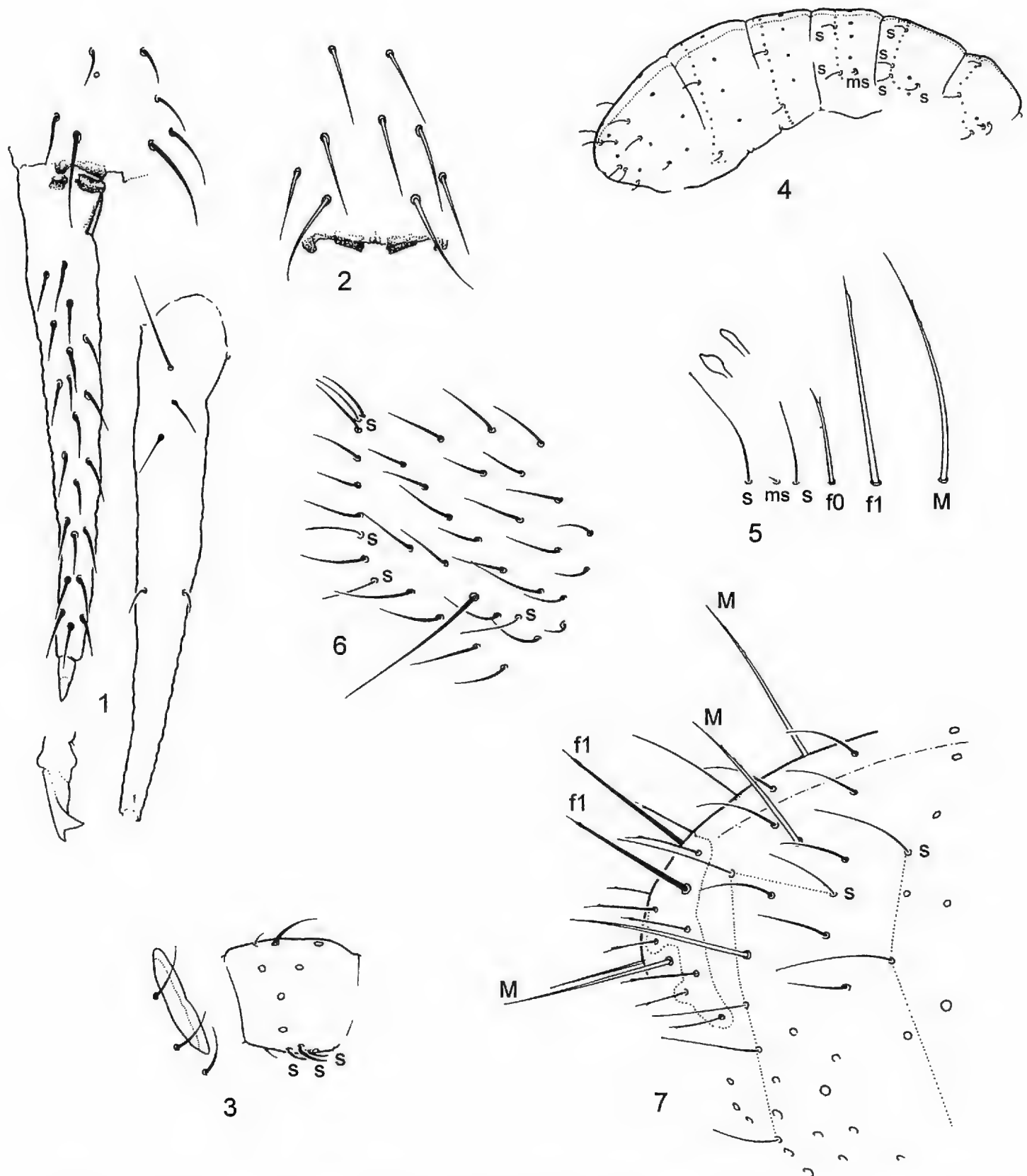
Etymology.—This species is named for Professor Wellingda Boni Sousa for enabling M. Culik’s research on Collembola in Brazil.

Material Examined.—See Types.

Discussion.—*Folsomia wellingdae* belongs to the *finetaria* group by having body sensilla in the p-row, absence of broadened sensilla on Abd. V, and presence of only one pair of macrosetae on each of Th. II and III. From all members of this group, *F. wellingdae* differs in having two “corner” sensilla on each side of the mesothorax (Figs. 4, 6) so each side of this segment bears 4 sensilla total. Each side of the mesothorax of all other species of *Folsomia* in which this character has been examined (Potapov 2001a, in press) bears 3 sensilla with a single “corner” sensillum (e.g., Potapov & Stebaeva 1977; Fig. 3).

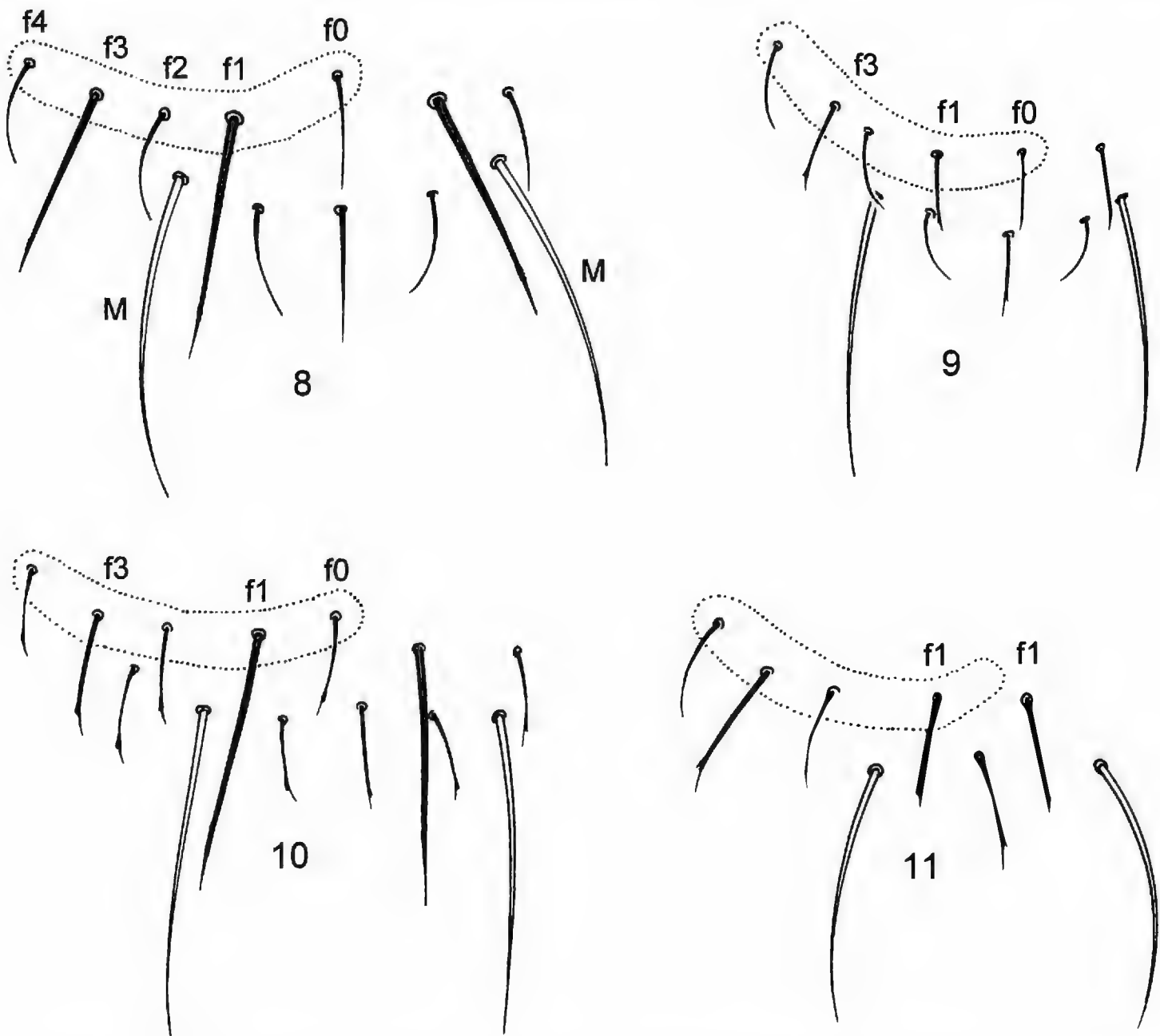
In addition, *F. wellingdae* differs from most members of the group, viz. *F. asiatica* Martynova, *F. candida* Willem, *F. ciliata* Babenko & Bulavintsev, *F. finetaria* (Linnaeus), *F. hidakana* Uchida & Tamura (sensorial chaetotaxy unknown), *F. nivalis* Packard and others, in the arrangement and/or number of setae on the anterior side of manubrium and dens. Two species, *F. kerni* Gisin (Switzerland) and *F. stella* Christiansen & Tucker (U.S.A., Iowa) have nearly the same anterior chaetotaxy of the furca. Like others, these two species have a single “corner” sensillum, inferred after the figure of the *F. stella* holotype by Christiansen & Tucker (1977) and after our own study of specimens of *F. kerni* from Slovakia (Kovac leg.).

Differences in Foil-setae.—Foil-setae are specific types of seta-like structures located only on Abd. VI and are distinguished by shape (Potapov 2001b, in press). Foil-setae (= foils) offer promise as a distinguishing taxonomical character in the *finetaria* group. Considerable differences in their shape and, more rarely, numbers are seen among closely related species. They appear to be all short (*F. nivalis*), with one (*F. wellingdae*) or two (*F. finetaria*) foils much longer and thicker, or reduced in number on the medial area (*F. kerni sensu mihi*). In addition, *F.*



Figures 1–7. *Folsomia wellingdae* Potapov & Culik, NEW SPECIES. Figure 1. Parts of furca (anterior side, dens posteriorly, mucro). Figure 2. Manubrium, anterior. Figure 3. PAO and Ant I. Figure 4. Arrangement of macrosetae, sensilla, and microsensilla on body. Figure 5. Seta-like structures (from left to right: laterodorsal sensillum of Abd. IV, microsensillum and apices of lateral sensilla of Abd. I, foil-setae of Abd. VI, macroseta of Abd. V). Figure 6. Chaetotaxy of mesothorax. Figure 7: Chaetotaxy of posterior part of abdomen; sensilla and foil-setae marked. f = foil-seta, M = macroseta, ms = microsensillum, s = sensillum.

wellingdae has all foils well differentiated, whereas in other species well differentiated foils alternate with undifferentiated ones (Figs. 8–11). The shape of the foil-setae sometimes varies slightly between populations and specimens within populations, but retains, however, differences between species.



Figures 8–11. Foil-setae of Abd. VI in members of the *fimetaria* group. Figure 8. *F. fimetaria* (Moscow, Russia). Figure 9. *F. nivalis* (Kamchatka, Russia). Figure 10. *F. wellingdae* Potapov & Culik, New Species. Figure 11. *F. kerni* (Slovakia, Kovac leg.). f = foil-seta, M = macroseta.

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José Aires Ventura, Jacimar Luis de Souza, and the Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural—INCAPER, Vitória, are thanked for support provided to M. Culik as a visiting scientist in Espírito Santo. We are much indebted to Lubo Kovac for providing specimens of *F. kerni*. This research was supported by a grant from the National Geographic Society for M. Culik and the Russian Foundation for Fundamental Research (grant 99-04-48165) for M. Potapov.

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A NEW SPECIES OF *UGANDATRICHIA* (TRICHOPTERA: HYDROPTILIDAE) FROM TAIWAN

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Abstract.—*Ugandatrachia*, a small but widespread Afrotropical-SE Asian-New Guinean genus of large hydroptilids is recorded here for the first time from Taiwan. A new species, *U. taiwanensis* Hsu and Chen n. sp., is described from central Taiwan, from adult males and females. The mature larva and pupa are also described and illustrated; the larval form and case formation differs considerably from the southern African species *U. rhodesiensis*, but similar to the southern Asian species *U. maliwan*, suggesting that the larval niche of the new species is probably the same as the Asian species.

Key Words.—Insecta, Trichoptera, Hydroptilidae, *Ugandatrachia*, Taiwan, New Species.

Ugandatrachia Mosely, 1939 is a small genus of hydroptilid caddisflies found in southern and central African, S and SE Asia to New Guinea, but until now, not recorded from Taiwan. Marshall (1979) revised the genus, providing diagnoses for adults, pupae and final instar larvae. Wells (1991), described a species from Papua New Guinea, added remarks on the genus and its possible affinities. Marshall based her discussion of larvae and pupae on the description by Scott (1976) of a southern African species collected from torrenticolous waters. Both Scott and Marshall note that the larvae show adaptations to this habitat. Malicky and Chantaramongkol (1991) found 3 new species from Thailand, and Malicky (1999) added remarks of larva morphology, pupa case, larva behavior and ecology of *U. maliwan* Malicky & Chantamogokal. The larva of the new species described here is also from fast flowing waters. Its features are quite different from those African species. The dome-shaped case resembles *U. maliwan* and those of many of the stactobiine larvae which feed on the surface of rocks, boulders and basement rock in streams and rivers. Rather than being strongly dorsoventrally flattened as the African species (Scott 1976), the Taiwanese larva is more cylindrical and it has three curious median sclerotized areas on the ventral abdomen as *U. maliwan*, rather than the regular abdominal tergites of *U. rhodesiensis*. The younger larva of Taiwan's species also play a commensalisms behavior with the older larva just the same as those of Thailand's *U. maliwan*. These evidences suggest differences in life style between the SE Asian and African specie groups. The terminology in this paper follows Marshall (1979).

MATERIALS AND METHODS

All specimens were collected by the senior author. Adults were collected by sweep-netting along the river banks, larvae and pupae were collected by hand-picking from small mountain rivers. All specimens were preserved in 75% alcohol. Adult genitalia were treated for 15 minutes with hot 10% KOH, then examined and illustrated under a stereo microscope. The holotype and some paratypes are deposited in the National Museum of Natural Science, Taiwan (NMNS); for the present, the remaining paratypes are stored in the Insect Laboratory of the Department of Biology, Tunghai University.

UGANDATRICHIA TAIWANENSIS HSU AND CHEN, NEW SPECIES

Description.—*Adult.* Body comparatively large, about 6.0 mm long, black to dark brown. Head and thorax as shown in Fig. 1. Wings (Fig. 2) slender, apically acute; forewing veins heavily sclerotized, especially the anal veins. Both wings densely covered with setae.

Male Genitalia (Figs. 3–5).—Abdominal segment VIII well developed, sternite broader than tergite. Segment IX with tergite membranous, sternite broad, lateral plate small. Tergite X small, swollen basally, forming two small lobes, in dorsal view pointed apically. Inferior appendages large and stout, densely pubescent, tapered distally, rounded apically, somewhat triangular in lateral view, with a small sclerotized median spur dorsally. Phallus long, distended towards base, tapered distally, ejaculatory duct slightly projected.

Female Genitalia (Figs. 6–7).—Abdominal segment VIII large, tergite rounded, sternite densely pubescent, greatly extended posteriorly. Sternite IX conical, divided distally. Segment X small, cylindrical, basally less than half the diameter of segment IX, with pair of small cerci apically.

Larva (Figs. 8–10).—Mature larva with head and thoracic sclerites black. Head flat, subrectangular in dorsal view. Thorax heavily sclerotized, margins dark and slightly irregular. Abdominal segment milky white, tergite IX only with sclerotized plates, no humps present, but median segments slightly swollen. Sternites III to V with rounded, brown, slightly sclerotized, median ventral plates. Tergite on segment IX dark. On segment X, two small, dark equal-sized sclerites; anal claws small but conspicuous, strongly furcate.

Pupae.—Immature pupa milky white, mandibles sharply tapered to acute apices. Abdominal tergite III to VIII (Figs. 12–13) with numerous sclerotized plates, posterior pair rounded, lateral pair oval, others irregular.

Larval Case (Fig. 14).—A semi-transparent, flattened, oval dome with margins perforated by one or two rows of circular holes; the case is attached to the rocky substratum at each end. Pupal cocoon is cigar- or “bon-bon”-shaped, and is developed within the larval dome.

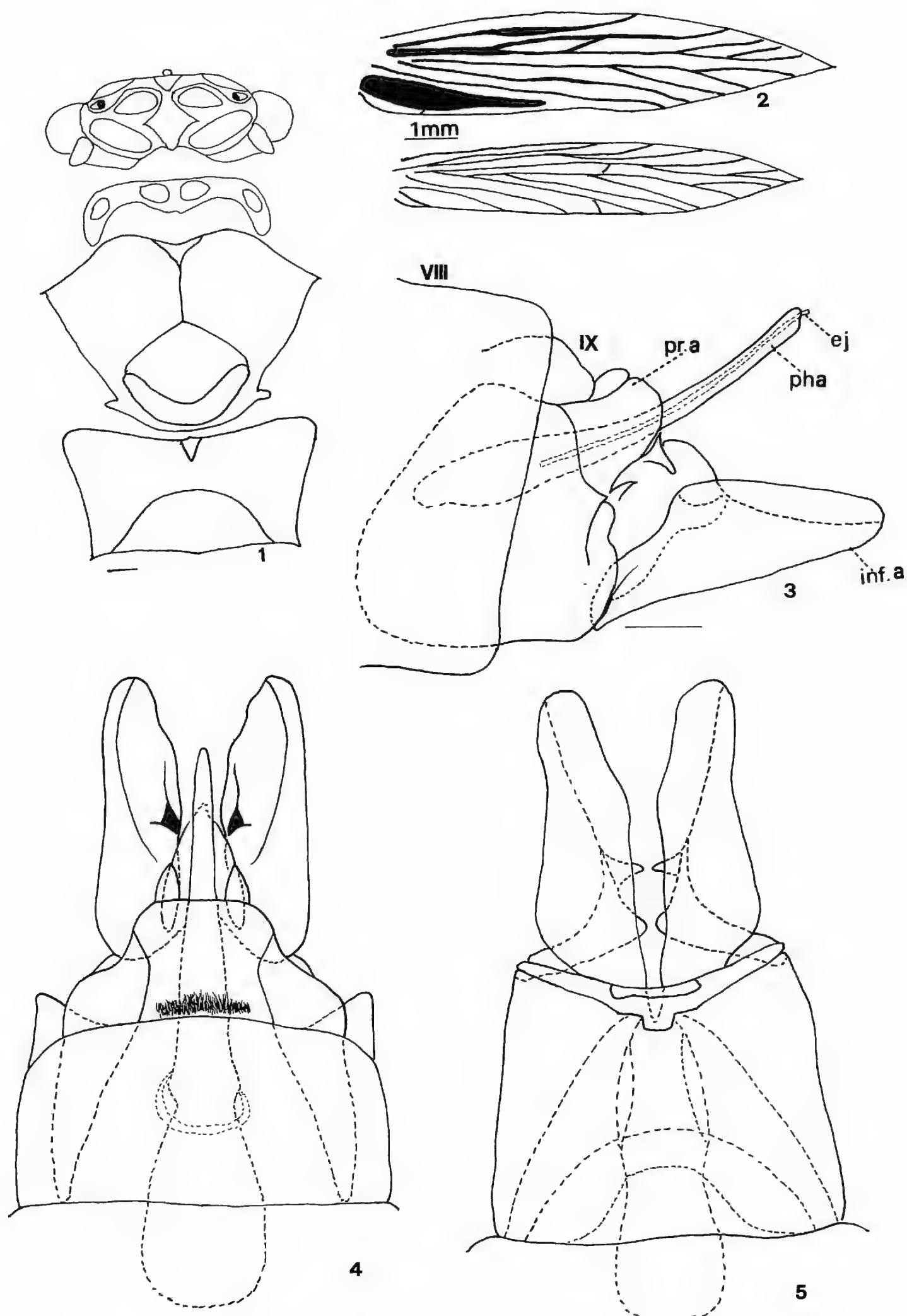
Diagnosis.—Adult of this species closely resembles the Vietnamese species *Ugandatrachia hairanga* Olah, 1989 (see also Wells & Huisman 1992), from which the male is distinguished by the form of the forewing and the shape of the inferior appendages in lateral view. *Ugandatrachia taiwanensis* lacks the patch of androconia on the forewing which characterizes males of the Vietnamese/West Malaysian species, but has distinctive heavily sclerotized anal veins and inferior appendages more slender basally. The form of the wings and the diamond-shaped mesoscutellum allow recognition of this species in the Taiwan hydroptilid fauna.

Types.—Holotype, male, TAICHUNG Co.: Shiwen Stream, 700 m, 21 Jan 1996. Paratypes, 1 female, same data as holotype; 2 male, 1 female, 46 larvae and pupae, TAICHUNG Co.: Dahrern Bridge, 800 m, 3 Mar 1996.

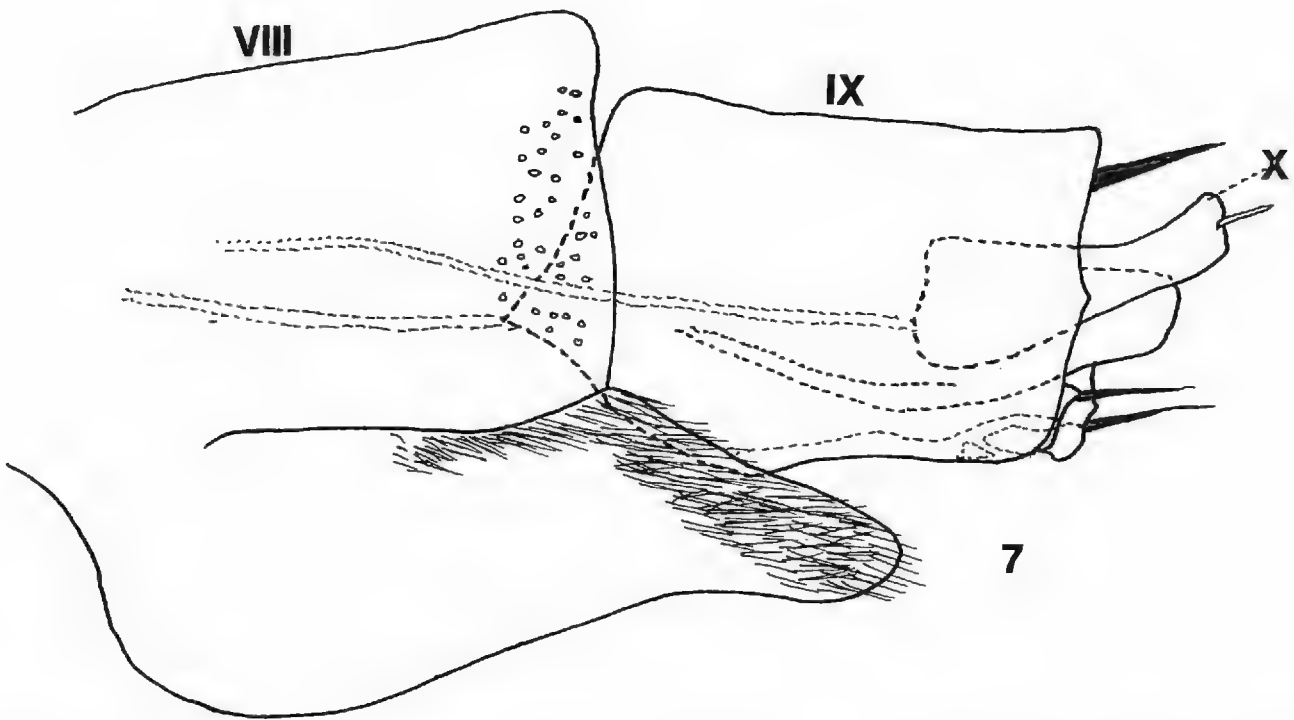
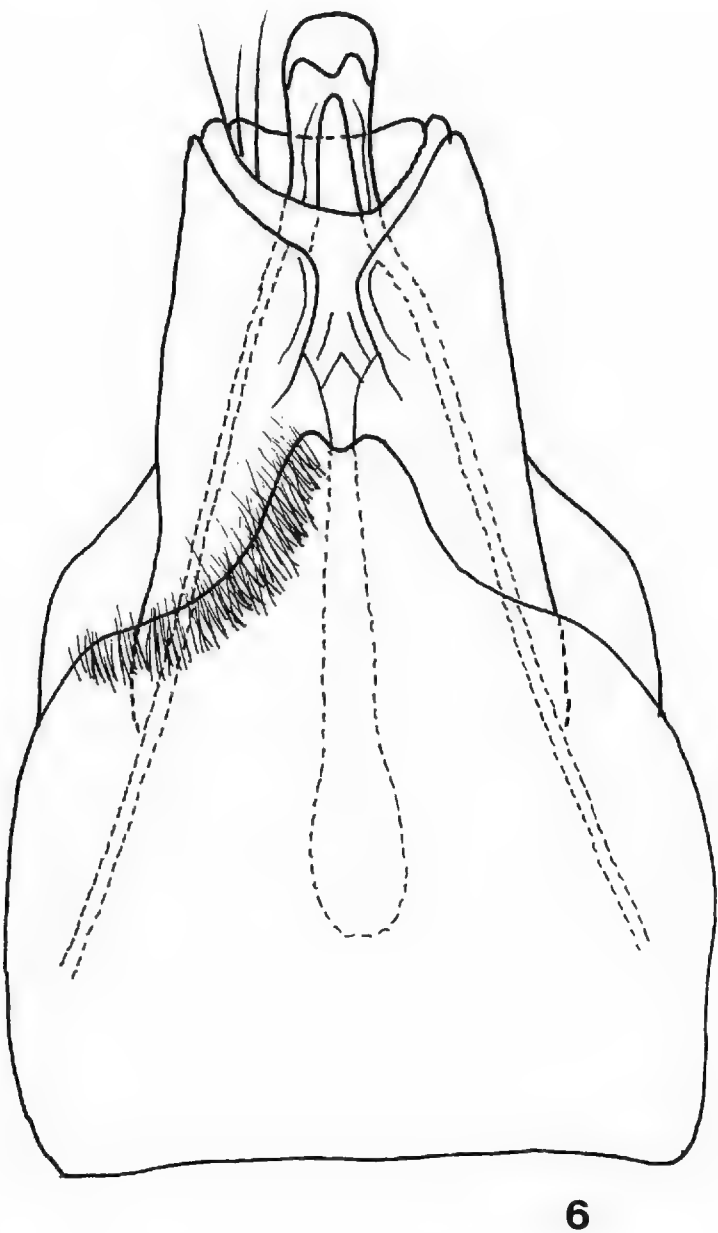
Remarks.—This species has been collected only in central Taiwan. Larvae live in small mountain brooks, the cases are attached to the rock surface, and were also taken from artificial waterfalls. The larvae of *U. taiwanensis* are similar to the larva of *U. maliwan* from Thailand, but differ in the case form, opening for larva, and sclerites of abdomen segments. A somewhat similar but unassociated larva has been collected from Vietnam (Royal Ontario Museum material, A. Wells, personal communication); its case shape differs and the ventral sclerites are more pronounced, giving the larva a curiously angular profile. It is possible that these larvae feed from the fixed case, the anterior part of the body swinging out across the rock surface, the ventral sclerites providing a tougher surface in contact with the abrasive rock.

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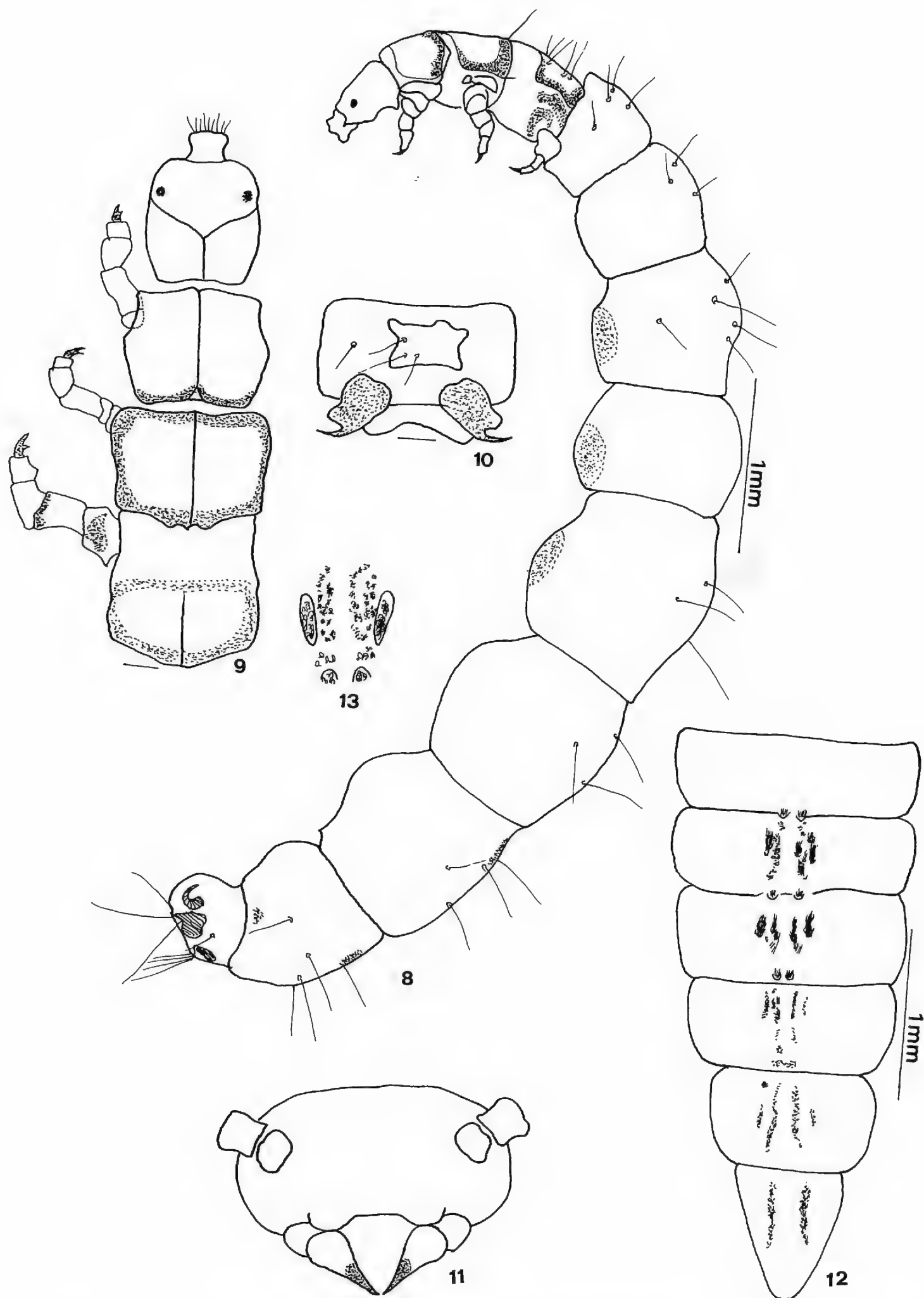
We thank Dr. A. Wells of Australia Biological Resources Studies, for reading this manuscript and providing valuable references. Thanks also to Dr. Hans Mal-



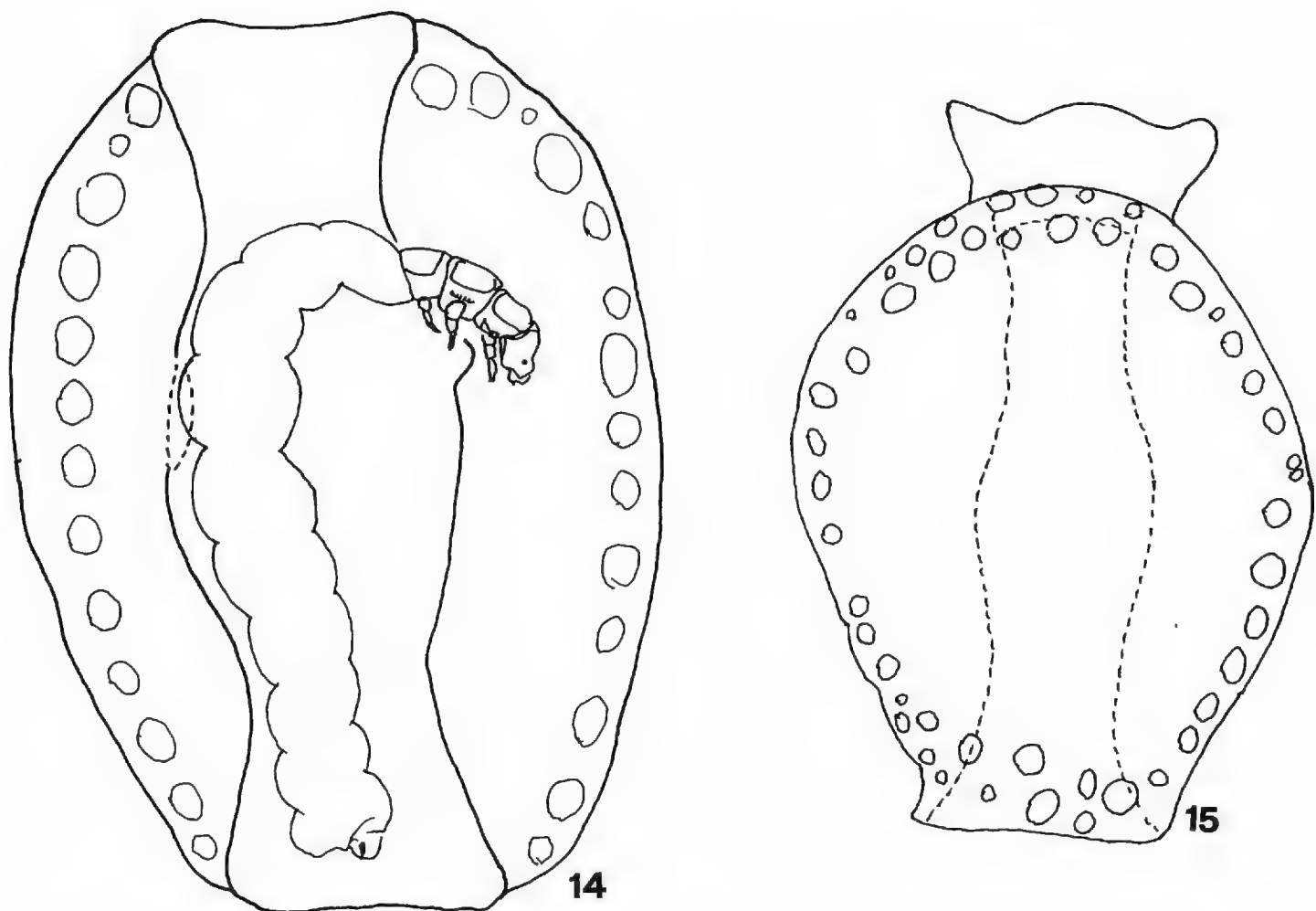
Figures 1–5. *Ugandatrachia taiwanensis* n. sp. Male taxonomic characters. Figure 1. Head and thorax (dorsal view). Figure 2. Forewing and hindwing. Figure 3. Genitalia, lateral view. Figure 4. Genitalia, dorsal view. Figure 5. Genitalia, ventral view. Abbreviation: VIII, abdomen segment VIII; IX, abdomen segment IX; X, abdomen segment of X; pr. a., preanal appendages; pha., phallus; ej., ejaculatory duct; inf. a., inferior appendages. The scale lines represent 0.1 mm unless indicated otherwise.



Figures 6–7. *Ugandatrachia taiwanensis* n. sp. Female taxonomic characters. Figure 6. Genitalia, ventral view. Figure 7. Genitalia, lateral view. The scale lines represent 0.1 mm unless indicated otherwise.



Figures 8–13. *Ugandatrichia taiwanensis* n. sp. Larva and pupa taxonomic characters. Figure 8. Larva, lateral view. Figure 9. Larva head and thorax, dorsal view. Figure 10. IX segment and anal hooks of larva, dorsal view. Figure 11. Head and thorax of pupa, frontal view. Figure 12. Abdomen of pupa, dorsal view. Figure 13. Sclerites of segment III to VIII of pupa, dorsal view. The scale lines represent 0.1 mm unless indicated otherwise.



Figures 14–15. *Ugandatrachia taiwanensis* n. sp. Larva and pupa case. Figure 14. Larva case with larva, dorsal view. Figure 15. Pupa cocoon, dorsal view.

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A REVISION OF THE GENUS *AGROSTEELLA* MEDVEDEV (CHRYSEMELIDAE: CHRYSEMELINAE)¹

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Abstract.—*Agrosteella* Medvedev is elevated to full generic status. The genus contains 8 species: *A. violaceicollis* sp. nov., *A. punctata* sp. nov., *A. jini* sp. nov., *A. biconvexa* sp. nov., *A. cheni* sp. nov., *A. oligotricha* sp. nov., *A. fallaciosa* (Stål), *A. medvedevi* (Daccordi). The male genitalia, pronotum and habitus of two species in this genus are illustrated. The type specimens are deposited in the Institute of Zoology, the Chinese Academy of Sciences, P. R. China (IZCAS).

Key Words.—Insecta, Coleoptera, Chrysomelidae, Chrysomelinae, *Agrosteella*, new genus, new species.

Agrosteella was originally erected as a subgenus of *Agrosteomela*, which was established by Medvedev (1987), the type species being *Agrosteomela fallaciosa* (Stål). Its main character is prosternum and metasternum are in the same plane, but are not connected, the mesosternum is between them, and most species with longitudinal depression in the middle of the prosternum. Body parallel-sided, not very convex, the rows of punctures of elytra distinct, the shape of the male genitalia is very different from the genus *Agrosteomela*. From the discussion above, we think the subgenus *Agrosteella* should be elevated to a full genus. It consists of 8 species, including 2 known species, 6 new species.

GENUS *AGROSTEELLA* MEDVEDEV

Agrosteomela (*Agrosteella*) Medvedev 1987, Ent. Viet. Acad. Nauk SSSR, Moscow: 72.—Daccordi, 2000, Ent. Basil., 25: 1.

Type Species.—*Agrosteomela* (*Agrosteella*) *fallaciosa* (Stål) by monotype.

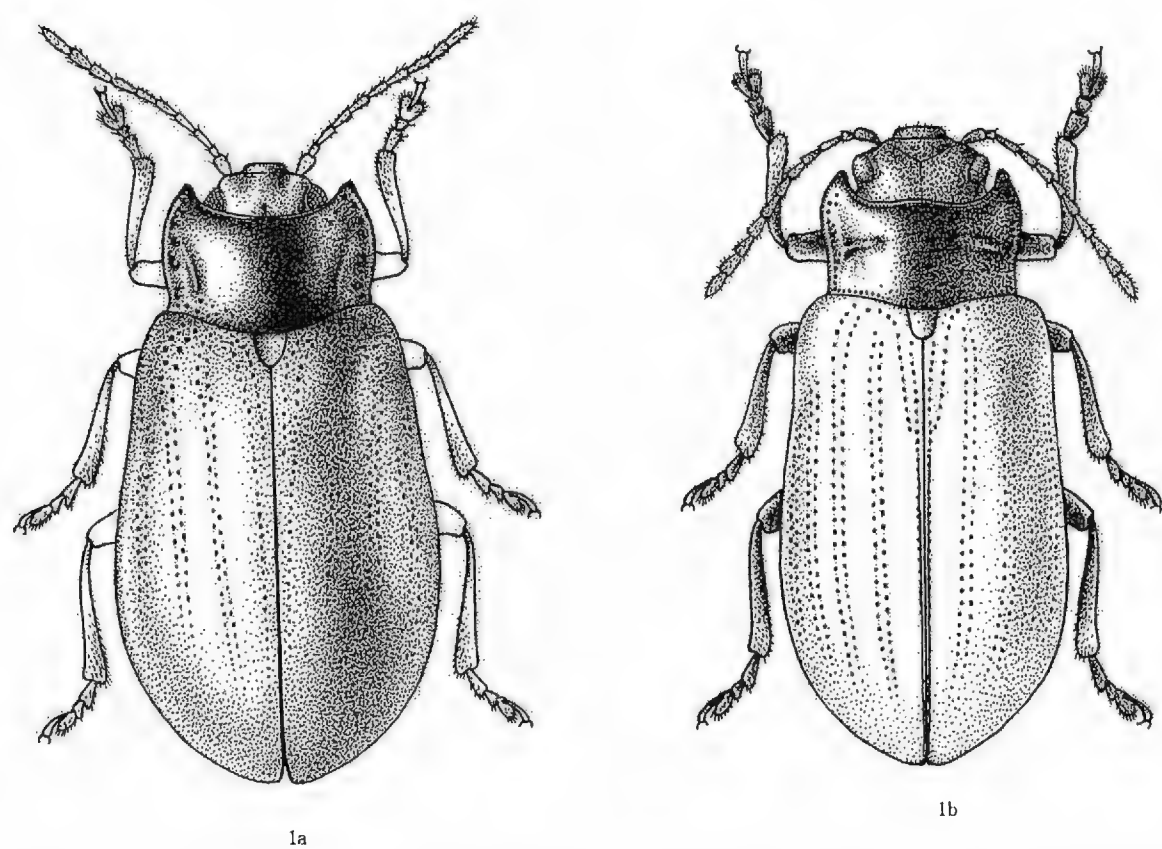
Description.—Body elongate, parallel-sided in outline. Head, thorax mostly metallic dark-green or purple; elytra mostly reddish-brown or yellowish-brown; sternites 3–5 reddish-brown. Clypeus narrow, two apical segments of maxillary palpi robust, and fourth segment truncate at apex. Antennae slender, extending beyond base of pronotum, first segment robust, almost elongate, second segment rounded, third slender, 2 or 2.5 times as long as second, remaining five apical segments slightly broadened apically. Prothorax much narrower at base than elytra, longer than broad, anterior margin widely emarginate with protruding anterior angles; central area of disc slightly convex, with sparse punctures; lateral margins of pronotum rounded or straight, with depression near lateral margins. Elytra striae distinct, interspace with punctures or impunctate; epipleuron broadened basally, strongly narrowed posteriorly, inner edge bearing a row of cilia-like fine hairs only at apex. Most species have longitudinal depression in middle of prosternum, and strongly punctate, apex of metasternum between mid coxae truncate, broadened, not covered mesosternum, this is the most important character of this genus. Anterior coxal cavities open, claws simple. Apical sternite of male trilobate, female pointed. Ventral view of male genitalia narrowing from base to apex, truncate or rounded apically.

Distribution.—Yunnan, Xizang; India, Nepal.

Eight species are presently known.

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² Correspondence author



Figures 1a–1b. Habitus of *Agrosteella*. Figure 1a. *A. fallaciosa* (Stål). Figure 1b. *A. biconvexa*, NEW SPECIES.

KEY TO THE SPECIES OF *AGROSTEELLA*

- 1. Coronal suture absent 2
- Coronal suture distinct 3
- 2. Metasternal process distinctly margined anteriorly ... *A. violaceicollis* sp. nov.
- Metasternal process not margined anteriorly *A. punctata* sp. nov.
- 3. Interspace between rows of punctures of elytra with fine punctures 4
- Interspace between rows of punctures of elytra without fine punctures ... 5
- 4. Length of longitudinal depression of pronotum extending beyond middle
..... *A. jini* sp. nov.
- Length of longitudinal depression of pronotum not extending beyond mid-
dle *A. fallaciosa* (Stål)
- 5. Middle portion of pronotum with transverse depression
..... *A. biconvexa* sp. nov.
- Middle portion of pronotum without transverse depression 6
- 6. Antennae segment 4 longer than each of 5–10, and shorter than 3
..... *A. cheni* sp. nov.
- Fourth segment of antennae subequal to each of 5–10 7
- 7. Metasternal process distinctly margined anteriorly ... *A. medvedevi* Daccordi
- Metasternal process not margined anteriorly *A. oligotricha* sp. nov.

AGROSTEELLA FALLACIOSA (STÅL), NEW COMBINATION
(Figs. 1a, 2a, 3a)

Paralina fallaciosa Stål, 1862, Nova. Acta. Upsal., 3(4): 5. —Weise, 1916, Col. Cat., Chrysomelinae, 24: 111.
Agrosteomela fallaciosa: Wang & Chen, 1981, Insects of Xizang, 1: 514. —

Chen & Wang, 1988, *In* Huang, F.Sh. (ed.), *Insects of Mt. Namjagbarwa region of Xizang*: 336.

Agrosteomela (Agrosteella) fallaciosa: Medvedev, 1987, *Ent. Viet. Acad. Nauk SSSR, Moscow*: 72. —Daccordi, 2000, *Ent. Basil.*, 25: 1.

Description.—Head, antennae, prothorax, legs, first sternite of abdomen metallic dark-green; two basal segments of antennae at apex, scutellum, elytra, underside of abdomen reddish-brown.

Head deeply inserted in prothorax, with sparse punctures and pubescence, pubescence of clypeus more dense than frons; clypeus divided into two parts by impressed line; between clypeus and labrum depressed emarginated. Maxillary palpi with fourth segment longer than third. Coronal suture distinct. Antennae segment 1 robust, elongate, second small, almost rounded, third longest, 2.5 times as long as second, 4–11 subequal, shorter than 3, longer than 2, 11 pointed at apex. Posterior angle of pronotum slightly blunt; central disc area with sparse punctures, lateral margins slightly rounded, with a shallow depression from posterior angle to anterior angle, not extending beyond middle, deep punctures in depression (Fig. 2a). Scutellum triangular with apex rounded, impunctate. Elytra punctures striae gradually obsolete by apical $\frac{1}{3}$ of apex, interspace with fine, dense punctures; epipleuron inner edge bearing a row of cilia-like fine hairs only at apex. Apex of metasternum not distinctly margined anteriorly. Male genitalia parallel-sided in ventral view, strongly narrowed and rounded apically (Fig. 3a). Length, 12.0 mm, breadth, 8.0 mm.

Material Examined.—India, 1932, 1 female, Clavareau.

Distribution.—India, Nepal (from reference).

AGROSTEELLA MEDVEDEVI (DACCORDI), NEW COMBINATION
(Figs. 2h, 3b)

Agrosteomela (Agrosteella) medvedevi, Daccordi, 2000, *Ent. Basil.*, 25: 1.

Description.—Body bright metallic green, elytra dark reddish-brown; two basal segments of antennae more or less reddish-brown at apex; clypeus pubescent on anterior margin, labrum almost black; abdomen red apically and on sides.

Head flattened, with an impressed line between clypeus and frons, finely and sparsely punctate. Coronal suture distinct, with more dense punctures than labrum. Antennae segment 1 robust, second small, third slender and 2 times as long as second, fourth shorter than third, equal to remaining segments. Central area of pronotum with surface smooth, with a few moderately strong punctures near base, laterally oblique depression with deep punctures between depressions and lateral margins (Fig. 2h). Scutellum triangular with apex rounded, impunctate. Elytra slightly widened behind, without post-basal impression; rows of punctures are distinctly striate, all interspaces smooth, without fine punctures. Underside shiny, almost impunctate and very finely pubescent. Apex of metasternum distinctly margined anteriorly. Male genitalia parallel-sided at base in ventral view, distinctly narrower apically, rounded at apex (Fig. 3b). Length, 11.3 mm, breadth, 6.4 mm.

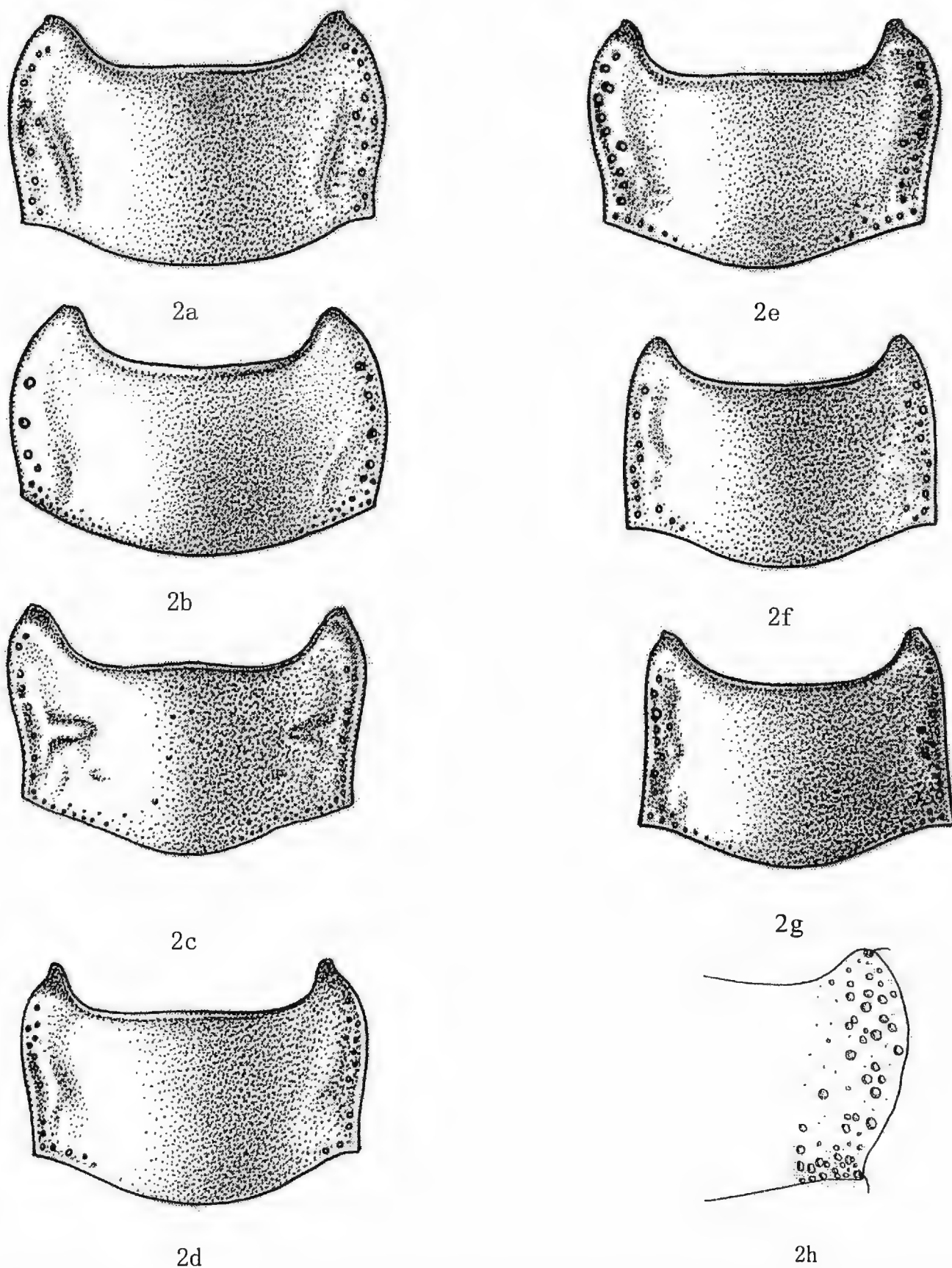
Distribution.—Nepal.

AGROSTEELLA CHENI, NEW SPECIES
(Figs. 2b, 3c)

Types.—Holotype male: China. Xizang, Mêdog, 1310 m, 11 Jul 1980, Jin and Wu. Deposited in the Institute of Zoology, The Chinese Academy of Sciences, P. R. China.

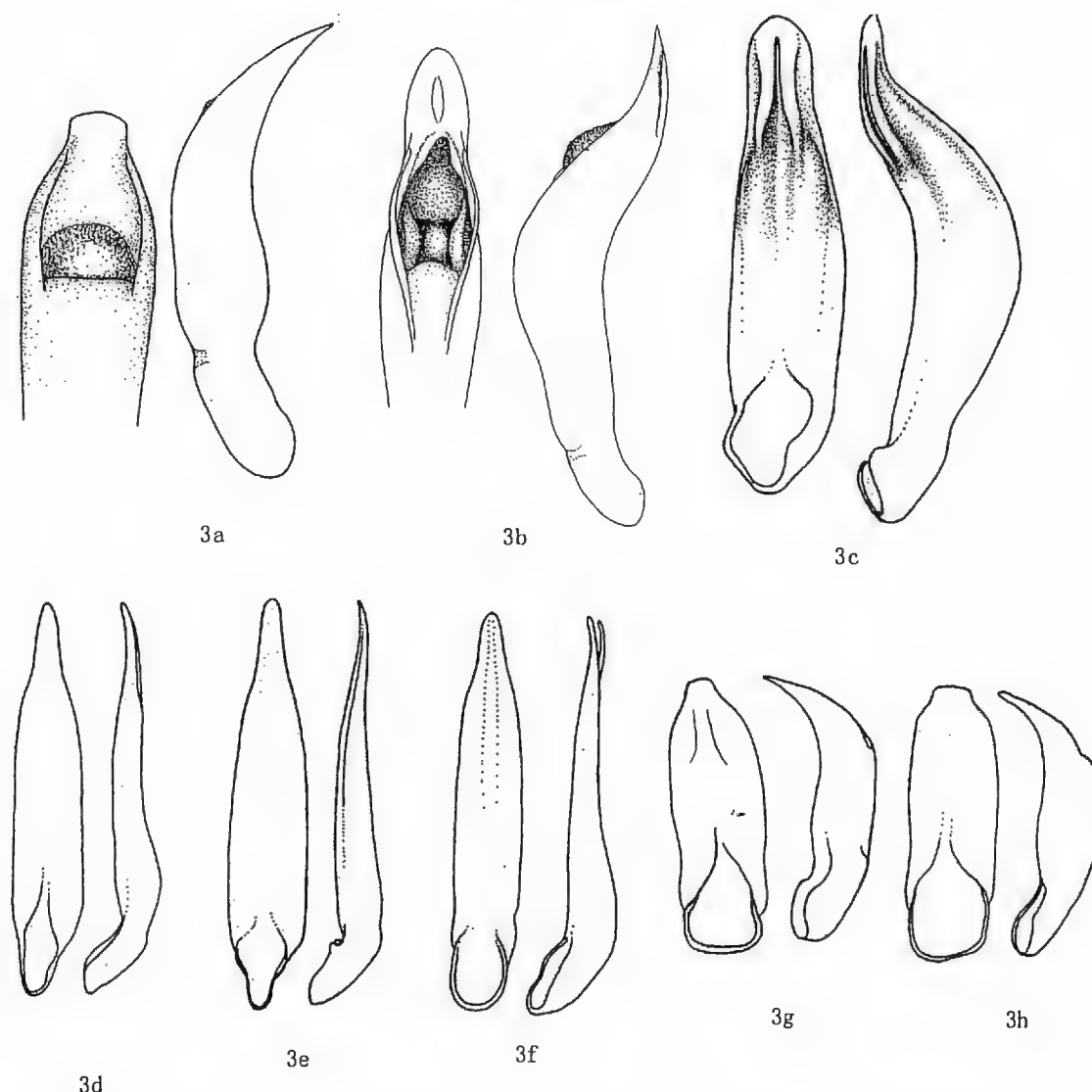
Description.—Head, thorax, legs, scutellum and basal segments of abdomen metallic green; two basal segments of antennae at apex, elytra, three apical segments of abdomen reddish-brown.

Head flat, labrum and frons with deep depression, fine punctures and pubescent. Coronal suture distinct, punctures of vertex closer and more than frons. Maxillary palpi with fourth segment shorter than third. Antennae segment 1 robust, semi-spherical, second small, spherical, third slender, 2 times as long as second, fourth shorter than third, subequal to remaining segments, 6–11 broadened, distinctly serrate. Pronotum with posterior angle straight, slightly bent outward; disc with fine punctures on



Figures 2a–2h. Pronotum of *Agrosteella*. Figure 2a. *A. fallaciosa* (Stål). Figure 2b. *A. cheni* NEW SPECIES. Figure 2c. *A. biconvexa* NEW SPECIES. Figure 2d. *A. oligotricha* NEW SPECIES. Figure 2e. *A. punctata* NEW SPECIES. Figure 2f. *A. violaceicollis* NEW SPECIES. Figure 2g. *A. jini* NEW SPECIES. Figure 2h. *A. medvedevi* (Daccordi), from Daccordi.

central area, lateral margins slightly rounded on innerside, with a short deep depression which is shorter than half of length of disc and with strong punctures (Fig. 2b). Scutellum triangular with apex rounded, impunctate. Elytra with punctures distinct in paired striae, not reaching apex of elytra, interspace flat, without fine punctures; epipleuron bearing a row of cilia-like sparse hairs only at apex. Apex of metasternum not distinctly margined anteriorly. Male genitalia parallel-sided (ventral view) with a deep depression, strongly narrowed near apex, rounded at apex, lateral view with a deep depression (Fig. 3c). Length, 10.8 mm, breadth, 6.2 mm.



Figures 3a–3h. Ventral and lateral view of *Agroteella*. Figure 3a. *A. fallaciosa* (Stål), from Daccordi. Figure 3b. *A. medvedevi* (Daccordi), from Daccordi. Figure 3c. *A. cheni* NEW SPECIES. Figure 3d. *A. biconvexa* NEW SPECIES. Figure 3e. *A. oligotricha* NEW SPECIES. Figure 3f. *A. punctata* NEW SPECIES. Figure 3g. *A. violaceicollis* NEW SPECIES. Figure 3h. *A. jini* NEW SPECIES.

Diagnosis.—The new species is similar to *A. fallaciosa* (Stål), but shape of male genitalia is very different.

Distribution.—Xizang.

Etymology.—This new species is named for the late Prof. S. H. Chen.

AGROTEELLA BICONVEXA, NEW SPECIES

(Figs. 1b, 2c, 3d)

Types.—Holotype male: China. Xizang, Yadong, 1250 m, 25 May 1980, Jin and Wu. Deposited in the Institute of Zoology, The Chinese Academy of Sciences, P. R. China.

Description.—Body elongate, slender in outline; head, thorax, scutellum and legs metallic purple; two basal segments of antennae at apex, elytra and underside of abdomen reddish-brown.

Head flat, between labrum and frons with depression, fine punctures. Coronal suture distinct. Antennae segment 1 robust, slender, second small, spherical, third slender, 2 times as long as second, fourth shorter than third, subequal to each remaining segment, from 5–11 broadened apically, distinctly serrate. Pronotum with posterior angle straight, slightly bent outward; central area of disc with sparse punctures; lateral margins slightly rounded, with a sublateral longitudinal deep depression posteriorly, a short transverse depression on middle portion near lateral margins (Fig. 2c). Scutellum triangular with apex rounded, impunctate. Elytra with punctures very distinctly in paired striae which reach the apex; interspace flat, impunctate; epipleuron bearing a row of cilia-like sparse hairs along apical half. Prosternum with median dense punctures in longitudinal depression; apex of metasternum not dis-

tinctly margined anteriorly. Ventral view of male genitalia parallel-sided, slender, narrowed near apex, rounded apically (Fig. 3d). Length, 11.0 mm, breadth, 6.5 mm.

Diagnosis.—The new species resembles to *A. punctata* sp. nov., but can be distinguished from latter by transverse depression near lateral margins of pronotum and interspace of punctate rows of elytra without fine punctures.

Distribution.—Xizang.

Etymology.—From the Latin, *biconvexa*, meaning two depression.

AGROSTEELLA OLIGOTRICA, NEW SPECIES

(Figs. 2d, 3e)

Types.—Holotype male: China. Xizang, Mêdog, 1200 m, 16 May 1980, Jin and Wu. Deposited in the Institute of Zoology, The Chinese Academy of Sciences, P. R. China.

Description.—Body metallic purple; two basal segments of antennae at apex, elytra, abdomen reddish-brown.

Head flat, with fine punctures, closer apically, a deep depression between labrum and frons. Coronal suture distinct; maxillary palpi with fourth segment shorter than third. Antennae short and broadened, first segment robust, second small, spherical, third slender, 2.5 times as long as second, fourth shorter than third, longer than remaining segments, 5–10 subequal in length, eleventh as long as fourth. Pronotum with posterior angle straight, slightly bent outward; center of disc with fine punctures; lateral margins somewhat straight, inside of which is a deep depression, especially posteriorly, with deep punctures (Fig. 2d). Scutellum triangular with apex rounded, impunctate. Elytra with punctures very distinct in paired striae which reach apex of elytra, interspace flat, impunctate; epipleuron bearing a row of cilia-like sparse hairs only at apex. Apex of metasternum not distinctly margined anteriorly. Male genitalia parallel-sided in ventral view, slender, narrowed near apex, rounded apically (Fig. 3e). Length, 11.5 mm, breadth, 7.0 mm.

Diagnosis.—The new species is similar to *A. biconvexa* sp. nov., but can be distinguished from latter by the depression of pronotum and the shape of male genitalia.

Distribution.—Xizang.

Etymology.—From the Latin, *oligotricha*, meaning sparse hairs.

AGROSTEELLA PUNCTATA, NEW SPECIES

(Figs. 2e, 3f)

Types.—Holotype male: China. Xizang, Mêdog, 1160 m, 7 Jul 1983, Han. Deposited in the Institute of Zoology, The Chinese Academy of Sciences, P. R. China.

Description.—Body dark-green, with metallic purple; clypeus, two basal segments of antennae at apex; elytra and abdomen reddish-brown.

Head flat, with sparse punctures, only clypeus with longer pubescence, deep concavity between labrum and frons. Coronal suture disappeared, maxillary palpi with fourth segment shorter than third. Antennae segment 1 robust, second small, third slender, 2 times as long as second, fourth shorter than third, longer than remaining segment, 5–11 subequal in length. Pronotum with posterior angle straight, slightly bent outward; disc with sparse punctures in central area, lateral margins more rounded apically, with a deep depression near its inner side containing strong punctures, especially at base (Fig. 2e). Scutellum triangular with apex rounded, impunctate. Elytra punctures in paired striae distinctly, reaching apex of elytra; interspace with dense, coarse punctures; epipleuron bearing a row of cilia-like sparse hairs only at apex. Apex of metasternum not distinctly margined anteriorly. Male genitalia parallel-sided in ventral view, slender, narrowed near apex, rounded apically (Fig. 3f). Length, 12.0 mm, breadth, 7.0 mm.

Diagnosis.—This species is similar to *A. biconvexa* sp. nov., but it can be distinguished from latter by punctures in the interspace of the elytra and the depression of pronotum.

Distribution.—Xizang.

Etymology.—From Latin, *punctata*, meaning coarse punctures.

AGROSTEELLA VIOLACEICOLLIS, NEW SPECIES

(Figs. 2f, 3g)

Types.—Holotype male, China. Yunnan, Xishuangbanna, Mengsong, 1600 m, 21 Apr 1959, Hong; allotype female, locality same as holotype, 1200–1400 m, 11 May 1958, Meng; paratype 3 female: locality same as holotype, 1 Jul 1958. Deposited in the Institute of Zoology, The Chinese Academy of Sciences, P. R. China.

Description.—Body dark-green with metallic purple; elytra, abdomen yellowish-brown.

Head flat, with fine punctures and pubescence, a deep depression between clypeus and frons. Coronal suture absent, maxillary palpi with fourth segment shorter than third. Antennae segment 1 robust, second small, spherical, third slender, 2 times as long as second, 4–10 subequal in length, shorter than third, eleventh longer than fourth, but shorter than third. Pronotum with posterior angle straight, slightly bent outward; center of disc with sparse punctures; lateral margins straight, with a deep depression just inside half length of disc and with deep punctures in it, especially at base (Fig. 2f). Scutellum triangular with apex rounded, impunctate. Elytra with punctures distinctly in paired striae, interspace with dense and coarse punctures; epipleuron bearing a row of cilia-like sparse hairs only at apex. Apex of metasternum distinctly margined anteriorly. Male genitalia parallel-sided in ventral view, slender, narrowed near apex, truncate at apex (Fig. 3g). Length, 10.0–11.0 mm, breadth, 6.0–6.5 mm.

Diagnosis.—The new species is similar to *A. jini* sp. nov., but it can be distinguished by shape of male genitalia and punctures of interspace.

Distribution.—Yunnan.

Etymology.—From the Latin, *violaceicollis*, meaning purple.

AGROSTEELLA JINI, NEW SPECIES

(Figs. 2g, 3h)

Types.—Holotype male: China. Xizang, Mêdog, 8 Sep 1979, Jin and Wu. Deposited in the Institute of Zoology, The Chinese Academy of Sciences, P. R. China.

Description.—Head, antennae, pronotum, scutellum, legs, first sternite of abdomen dark-green, with metallic purple; two basal segments of antennae at apex, elytra, and 2–5 sternites dark-brown.

Head flat, with fine punctures and pubescence, a deep depression between clypeus and frons. Coronal suture distinct, maxillary palpi with fourth shorter than third. Antennae segment 1 robust, second small, spherical, third slender, 2 times as long as second, 4–10 subequal in length, eleventh slightly longer than tenth, shorter than third. Pronotum longer than broad, anterior margin deeply emarginated with protruding anterior angles, anterior angles pointed, posterior angle straight, slightly bent outward; center area of disc with sparse punctures; lateral margins straight, with a deep longitudinal depression just inside, which is longer than half of length and with deep punctures, especially at base (Fig. 2g). Scutellum triangular with apex rounded, impunctate. Interspace of elytra with dense, coarse punctures; epipleuron bearing a row of cilia-like sparse hairs at apex. Apex of metasternum not distinctly margined anteriorly. Male genitalia parallel-sided in ventral view, slender, narrowed near apex, truncated at apex (Fig. 3h). Length, 11.2 mm, breadth, 6.8 mm.

Diagnosis.—The new species is similar to *A. violaceicollis* sp. nov., but it can

be distinguished from latter by shape of male genitalia and punctures of interspace of striae on elytra.

Distribution.—Xizang.

Etymology.—This new species is named for Prof. G. T. Jin.

DISCUSSION

Agrosteella belongs originally to a subgenus of *Agrosteomela*, based on the protruding metasternum, which does not cover mesosternum. Furthermore, we found an additional five different characters between *Agrosteella* and *Agrosteomela*, as follows:

1) Body of *Agrosteella* slender, almost parallel-sided, but *Agrosteomela* almost robust and broadened at apex.

2) The lateral margins of pronotum more straight posteriorly in *Agrosteella*, central disc with distinct depression and punctures, but in *Agrosteomela* lateral margins of pronotum rounded, central disc without distinct depression and punctures.

3) The pairs rows of elytral punctures distinct in *Agrosteella*; in *Agrosteomela* not distinct.

4) Epipleuron bearing a row of cilia-like sparse hairs only at apex in *Agrosteella*, but most species in *Agrosteomela* epipleuron bearing a row of cilia-like sparse hairs throughout the length.

5) The shape of male genitalia is very different.

From the discussion above, we think these differences are enough to elevate the subgenus *Agrosteella* to genus status.

According to the comparative morphological research, we primary suggest dividing *Agrosteella* into three groups: the 1 group is *A. violaceicollis* sp. nov., *A. fallaciosa* (Stål) and *A. jini* sp. nov.; the 2 group is *A. punctata* sp. nov., *A. biconvexa* sp. nov., *A. medvedevi* Daccordi and *A. oligotricha* sp. nov.; the 3 group is *A. cheni* sp. nov. From the following figures, it is apparent that the shape of male genitalia is different between groups: in the 1 group, narrowed from the middle to the apex and truncated at apex; in the 2 group, it is slender, rounded at apex; in the 3 group, it is robust, sclerotized strongly, and with a deeply longitudinal depression.

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STUDIES ON THE CHRYSOMELIDAE (COLEOPTERA) OF THE BAJA CALIFORNIA PENINSULA: THE GENUS *DYSPHENGES* HORN (GALERUCINAE: ALTICINI)

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Abstract.—Three new species of the genus *Dysphenges* are described from Baja California Sur, and the once monotypic genus and species are redescribed. Host and distribution information is presented, and a key to the known species is included.

Key Words.—Insecta, Coleoptera, Chrysomelidae, Galerucinae, Alticini, *Dysphenges*, *eichlini*, *elongatulus*, *lagunae*, *rileyi*, Mexico, Baja California peninsula, Baja California Sur, Arizona.

The genus *Dysphenges* was created by Horn (1894) for a unique species, *D. elongatulus*, from Baja California. Since then, very little attention has been given to this genus. Although the cape region of Baja California Sur is in the Sinaloan Province of the Neotropical Region (Udvardy 1975), Scherer (1983) did not include *Dysphenges* in his key to the genera of Neotropical Alticinae, or in the updated list of genera. *Dysphenges* would be included in Scherer's "group 6" and would key to *Phyllotreta* Chevrolat or *Phyllotrupes* Hope, depending on the interpretation of "antennal calli poorly defined" (according to Seeno & Wilcox (1982), Furth & Suzuki (1992), Furth & Savini (1996), *Platiprosopus* Chevrolat is the valid name for *Phyllotrupes*). Arnett (1968) did not include *Dysphenges* in his key to the genera of North American Alticinae, but did list *D. elongatulus* from Baja California. Seeno and Wilcox (1982) listed *Dysphenges* from North and Central America. Wilcox (1975) recorded *D. elongatulus* from Texas, but this is most likely in error. There are two species of *Dysphenges* in Arizona and at least one species in Texas and Missouri. The Texas-Missouri species and one of the Arizona species are undescribed. The second Arizona species is one described in this paper. The undescribed North American species most likely led to the error in reporting *D. elongatulus* from Texas. Blackwelder (1946) and Leng (1920) record *D. elongatulus* only from Baja California and Lower California, respectively; Furth and Savini (1996) repeat this distribution. The authors have not seen specimens of *D. elongatulus* from localities outside the cape region of Baja California Sur. From specimens collected and data acquired by the authors, there appear to be additional undescribed species from northern Mexico and Baja California Sur. The species from Baja California Sur are treated here as a part of an on-going study of the Chrysomelidae of the Baja California peninsula. The other species will be addressed in a future work.

Specimens of three different color forms of *Dysphenges* were collected by the authors at a number of sites in the cape region of Baja California Sur. Only one color form was collected from any specific bush at a site. This, along with possible elevational separation of these color forms, suggested that more than one species

was present in the cape region. Our study has confirmed that these forms represent three separate species. A specimen of a fourth species was subsequently discovered in the collection of the California Academy of Sciences. This latter species is from the highest elevations of the Sierra de La Laguna. The La Laguna area has provided many unique species of Chrysomelidae. This area is remote and inaccessible by motor vehicles. To date, the authors have not been able to collect this area.

Specimen Depositories.—AJGC—Arthur J. Gilbert collection, CASC—California Academy of Sciences, CDFA—California Department of Food & Agriculture, EGRC—Edward G. Riley collection, FMNH—Field Museum of Natural History, MCZC—Museum of Comparative Zoology, SDCM—San Diego County Museum of Natural History, TAMU—Texas A & M University, UCBC—University of California, Berkeley, UNAM—Universidad Nacional Autónoma de México.

DYSPHENGES HORN

Dysphenges Horn, 1894: 408. Type Species.—*Dysphenges elongatulus* Horn, 1894, by original designation.

Redescription.—Form elongate; 1.80–2.70 mm in length. Head oval; eyes entire; antennae separated by interantennal carina; frontal tubercles faintly indicated; labrum moderately large, feebly emarginate; apical palpomere acute; antennae slightly longer than half length of body, thicker towards apex; antennomeres 2–3 subequal in length, shorter than antennomere 1; antennomeres 4–10 subequal in length, each usually shorter than antennomere 11. Pronotum transverse, glabrous, without basal or longitudinal impressions, anterior corner angles distinct, acute. Scutellum triangulate, glabrous, shining, impunctate. Elytra slightly wider than pronotum, glabrous, each with scutellar row and nine complete, regular rows of punctures; elytral apices subtruncate; epipleuron subvertical, uniformly broad for entire length. Pygidium exposed beyond elytra. Prosternum narrow between coxae; front coxal cavities closed behind. Male with last ventrite lobed. Legs with hind femur reaching elytral apex; hind legs with first tarsomere slightly longer than two and three combined; tarsal claws appendiculate.

Diagnosis.—The genus *Dysphenges* can be distinguished from all other North American alticine genera, except *Glenidion* H. Clark, by a uniformly broad, subvertical elytral epipleuron (Figs. 19, 21); a subtruncate elytral apex (Figs. 18, 20) and the metafemora reaching the elytral apex (Figs. 19–21). *Dysphenges* can be distinguished from *Glenidion* by the lack of a prebasal transverse impression on the pronotum (Figs. 18, 20).

Remarks.—Horn's type series of three specimens from the Baja California peninsula is a mixed collection of two species; one specimen is *D. elongatulus* and two are *D. eichlini* new species (below). Two of these specimens are in the collection of the California Academy of Sciences. Both are dissected females with the spermathecae slide mounted on the pin. One is a piceous specimen and is designated as the lectotype of *D. elongatulus*. The other is a rufotestaceous specimen typical of *D. eichlini* and has been labeled as a paratype of this species. A third syntype is in the collection of the Field Museum of Natural History. It is also a rufotestaceous specimen typical of *D. eichlini*. The latter specimen is not dissected. This specimen has also been labeled as a paratype of *D. eichlini*. Horn did not indicate in his original paper the number of specimens included in the type series; it appears that there are only three. A fourth specimen in the collection of the Museum of Comparative Zoology has the locality label "El Taste." It is

labeled exactly like the two specimens in the California Academy of Sciences collection, but it lacks a type label indicating that it was part of the original series. This specimen is also typical of *D. eichlini* and has been labeled as a paratype of this species.

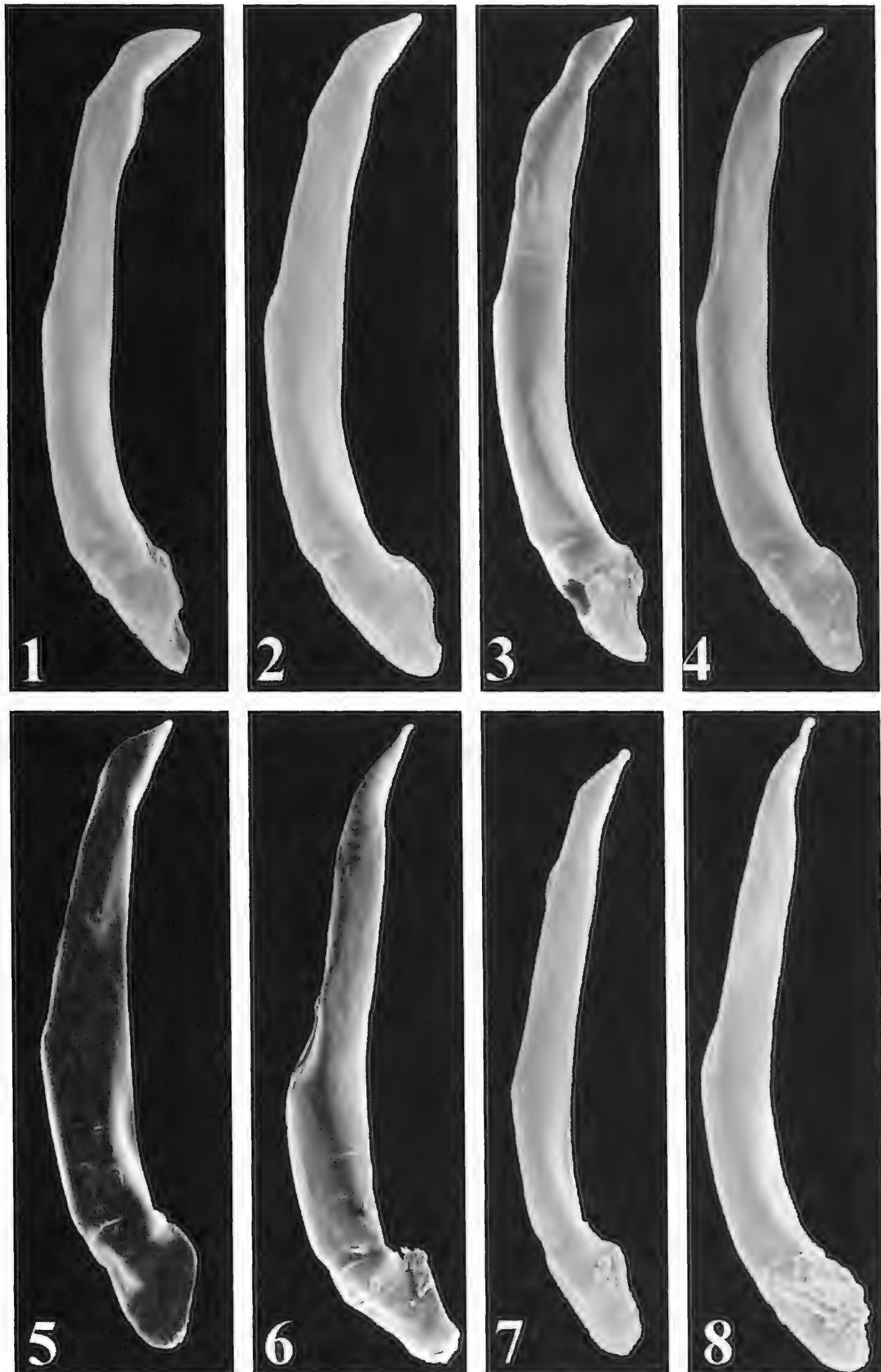
KEY TO THE DESCRIBED SPECIES OF *DYSPHENGES*

- 1. Elytra uniformly colored, testaceous to piceous 2
- 1'. Elytra light testaceous with fuscous markings along suture, apex and epipleura (Figs. 18, 19); aedeagus as in Figs. 1–5, 9 and spermatheca as in Fig. 15 *rileyi* Gilbert & Andrews, NEW SPECIES
- 2. Elytra rufotestaceous; aedeagus as in Figs. 8, 12
..... *eichlini* Gilbert & Andrews, NEW SPECIES
- 2'. Elytra fuscous to piceous 3
- 3. Frons and vertex sparsely, minutely punctate; pronotal punctures moderately coarse; elytral punctures moderately coarse and mostly separated by less than diameter of puncture; aedeagus as in Figs. 7, 10
..... *elongatulus* Horn
- 3'. Frons and vertex coarsely, uniformly punctate; pronotal punctures coarse; elytral punctures coarse and mostly separated by more than diameter of puncture; aedeagus as in Figs. 6, 11
..... *lagunae* Gilbert & Andrews, NEW SPECIES

DYSPHENGES EICHLINI GILBERT & ANDREWS, NEW SPECIES
(Figs. 8, 12, 13)

Types. Holotype (male) (CASC # 17712): MEXICO. BAJA CALIFORNIA SUR: Ramal Naranjas Rd., 11.7 km (7.3 mi) W Highway 1, 455 m (1500'), 1 Sep 1990, F. Andrews, T. Eichlin & A. Gilbert. Allotype (female): MEXICO. BAJA CALIFORNIA SUR: 14.0 km (8.7 mi) N Santa Anita, 197 m (650'), 5 Sep 1990, F. Andrews, T. Eichlin & A. Gilbert. Holotype and allotype deposited in the California Academy of Sciences. Paratypes (49)—same data as holotype (7) [CDFA], (2) [UNAM]; same data as allotype, except collected from *Mimosa purpurascans* Robinson (15) [AJGC], (2) [TAMU]; same data as allotype (15) [CDFA]; Las Barracas, ca. 30 km E. Santiago, 1/7 Dec 1982 (1) [UCBC]; Las Barracas, ca. 30 km E. Santiago, 7/12 May 1982 (1) [UCBC]; Ramal Naranjas Rd., 4.7 km (2.9 mi) W Highway 1, 197 m (650'), 1 Sep 1990, F. Andrews, T. Eichlin & A. Gilbert (1) [AJGC]; 11.6 km (7.2 mi) W on Ramal a Los Naranjas, 15 Sep 1988 (2) [EGRC]; El Taste (1) [CASC]; El Taste, Baja Cal., VIII,-IX,01 (1) [FMNH]; El Taste (1) [MCZC].

Description.—Male (holotype). Length 2.10 mm; width at elytral humeri 0.80 mm; form elongate. Color predominantly rufotestaceous, except central portion of elytra lighter. Head alutaceous, coarsely, regularly punctate, rufotestaceous except labrum and mandibles testaceous; eyes entire; frontal tubercles faintly indicated; interantennal carina distinct, broad; interantennal space approximately 1.5 times wider than space between eye and antennal socket (measured at narrowest point); antennae extending nearly to center of elytra; antennomeres 1–3 testaceous; 4–11 becoming darker; antennomeres 2–3 subequal in length, shorter than antennomere 1, and 4–11; antennomeres 4–11 subequal in length. Pronotum 1.4 times wider than long, alutaceous, glabrous, densely, uniformly punctate with punctures equal in size to those of elytral striae. Scutellum rufotestaceous, triangular, impunctate. Elytra together 1.4 times longer than wide, glabrous, alutaceous; punctures coarse, mostly separated by less than



Figures 1–8. Male aedeagus, lateral view. Figures 1–3. *Dysphenges rileyi* (El Triunfo). Figure 4. *D. rileyi* (Guillermo Prieto). Figure 5. *D. rileyi* (Sycamore Canyon, Ariz.). Figure 6. *D. lagunae*. Figure 7. *D. elongatulus*. Figure 8. *D. eichlini*.

diameter of puncture, arranged in short scutellar row and nine complete longitudinal rows, regularly placed within rows except basal half of first row somewhat confused with scutellar row; elytral apex subtruncate with outer angle rounded, inner angle more square; epipleura rufotestaceous, darker than disc, wide throughout entire length (at least as wide as two elytral intervals at widest point), with scattered, very coarse punctures. Pygidium exposed beyond elytra. Venter with metasternum and abdomen fuscous (except last ventrite, lighter); last ventrite with broad lobe and with dark median longitudinal line extending entire length of segment. Legs entirely rufotestaceous. Genitalia as in Figs. 8 and 12.

Female (allotype). Similar to holotype, except larger, with length 2.10 mm; width at elytral humeri 0.85 mm. Last ventrite without apical lobe. Spermatheca as in Fig. 13.

Variation.—Male: length 1.80–2.30 mm; width at elytral humeri 0.70–0.90 mm; Female: length 1.60–2.40 mm; width at elytral humeri 0.70–1.00 mm.

Diagnosis.—*Dysphenges eichlini* is differentiated from all other species in the genus by the rufotestaceous coloring of the elytra and most other body parts. The aedeagus (Figs. 8, 12) will provide positive identification. A single female specimen (non-paratype) from northeast of Guillermo Prieto, collected at blacklight, is tentatively placed as *D. eichlini*. The specimen is female and appears to have been teneral when collected; therefore, the characters needed for positive placement are lacking or difficult to observe.

Distribution.—Known only from Baja California Sur (Figs. 16–17). The single tentatively placed specimen from northeast of Guillermo Prieto extends the range to near the state of Baja California. It is probable that this species will be found in this state at a future date.

Host.—One series of seventeen specimens was collected from *Mimosa purpurascens* Robinson (Fabaceae) (misspelled on the label). See comments under host for *D. rileyi* new species (below).

Etymology.—Named for Thomas D. Eichlin for his many contributions to insect systematics.

Material Examined.—See types. Also one non-paratype. MEXICO. BAJA CALIFORNIA SUR: 1.6 km (1.0 mi) NE Guillermo Prieto, 19/20 Jul 1999, 27°48'32"/113°18'31", BL, R. Aalbu & K. Brown (1) [CDFA].

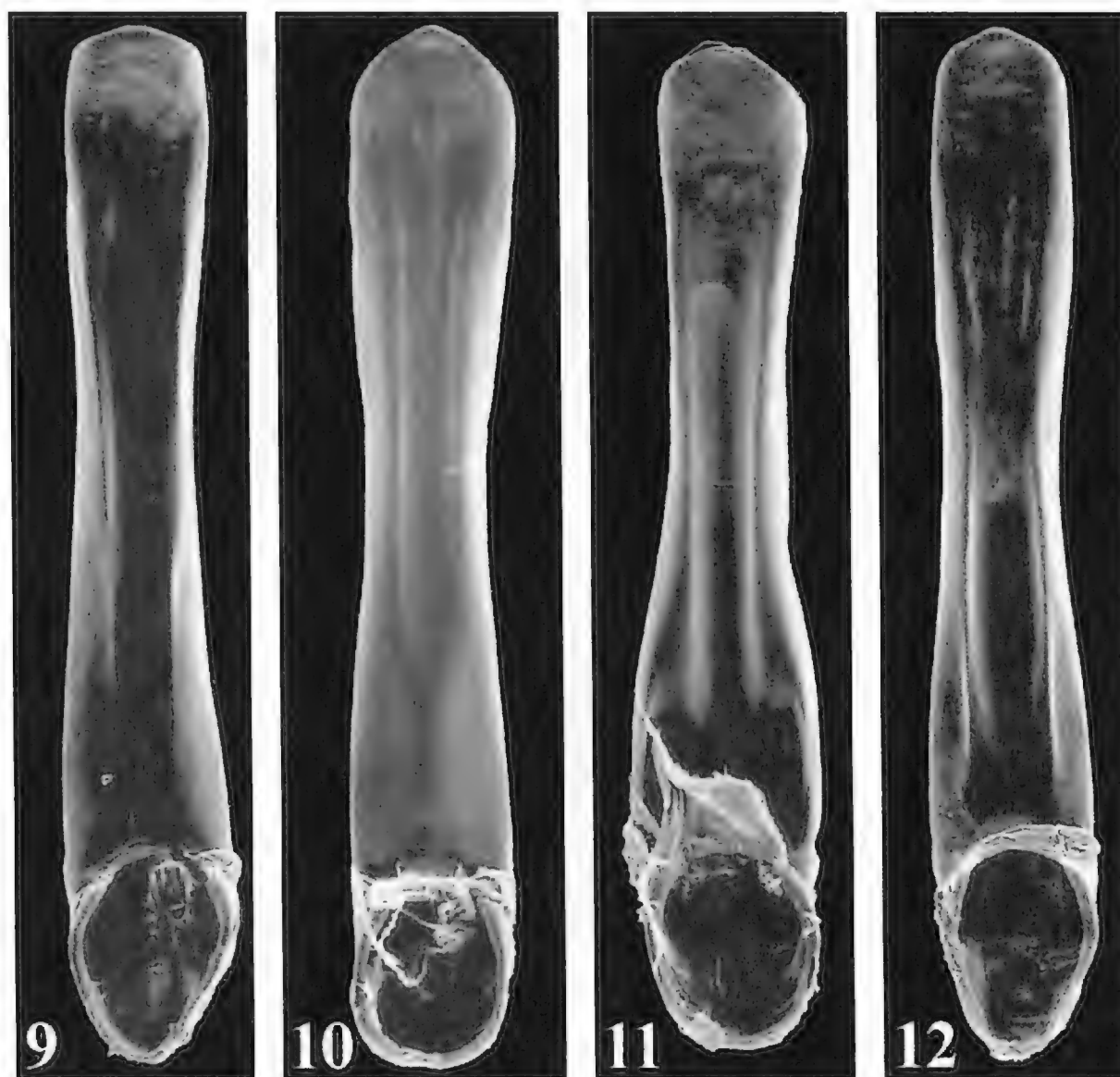
DYSPHENGES ELONGATULUS HORN

(Figs. 7, 10, 14, 20–21)

Dysphenges elongatulus Horn, 1894: 409.

Type. Lectotype (here designated): female; El Taste. Labeled as the lectotype by the authors and deposited in the California Academy of Sciences.

Redescription.—Male. Length 2.20 mm; width at elytral humeri 0.80 mm; form elongate: Color fuscous to piceous, except face, antennae, and legs lighter to varying degrees. Head with vertex fuscous and face testaceous; vertex indistinctly alutaceous, finely, sparsely punctate; eyes entire; frontal tubercles faintly indicated, smooth, flat, separated by small pit; interantennal carina distinct, narrow; interantennal space only slightly wider (1.1×) than space between eye and antennal socket; antennae extending nearly to center of elytra; antennomeres 1–7 testaceous (but lighter than face); antennomeres 8–11 darker; antennomeres 2–3 subequal in length, shorter than antennomeres 1, and 4–10; antennomeres 4–10 subequal in length, but each shorter than 11. Pronotum 1.3 times wider than long (measured at the center line), shining, glabrous, uniformly punctate, with punctures slightly smaller and less coarse than elytral punctures; anterior corners forming acute, laterally projecting tooth. Scutellum triangulate, glabrous, shining, impunctate. Elytra 1.4 times longer than wide, shining, glabrous, inconspicuously alutaceous; punctures coarse, arranged in short scutellar row and nine complete longitudinal rows, with punctures within rows regularly placed, except those in basal half of first row



Figures 9–12. Male aedeagus, ventral view. Figure 9. *D. rileyi*. Figure 10. *D. elongatulus*. Figure 11. *D. lagunae*. Figure 12. *D. eichlini*.

somewhat confused with those of scutellar row; elytral apex subtruncate with corners rounded; epipleura wide throughout entire length (at least as wide as two elytral intervals at widest portion), with scattered, coarse punctures (larger than those of elytral disc). Pygidium exposed beyond elytra. Venter finely punctate, fuscous (except last ventrite lighter medially); last ventrite with broad, short lobe and dark median longitudinal line extending length of segment. Legs with femora fuscous, tarsi testaceous, tibia intermediate in color. Genitalia as in Figs. 7 and 10.

Female (lectotype). Similar to male, except larger, with length 2.55 mm, width at elytral humeri 0.95 mm. Last ventrite entirely fuscous, without dark longitudinal line or apical lobe. Spermatheca as in Fig. 14.

Variation.—Male: length 1.80–2.40 mm; width at elytral humeri 0.80–0.90. Female: length 1.90–2.70 mm; width at elytral humeri 0.70–1.10 mm.

Diagnosis.—*Dysphenges elongatulus* is differentiated from *D. rileyi* and *D. eichlini* externally by its completely fuscous coloration and from *D. lagunae* new species (below), by the more closely placed punctation of the elytral striae and the minute, sparse punctation of the frons and vertex. Examination of the aedeagus (Figs. 7, 10) will provide positive identification.

Distribution.—Known only from Baja California Sur (Figs. 16–17).

Host.—Unknown.

Material Examined.—(69)—MEXICO. BAJA CALIFORNIA SUR: 15.5 km (9.6 mi) W. hwy 1 on Ramal Sn Antonio de la Sierra, 19 Sep 1988, A. J. Gilbert (9) [AJGC]; 15.5 km (9.6 mi) W hwy 1 on Ramal Sn Antonio de la Sierra, 19 Sep 1988, E. G. Riley (1) [EGRC]; 24.8 km (15.4 mi) W. hwy



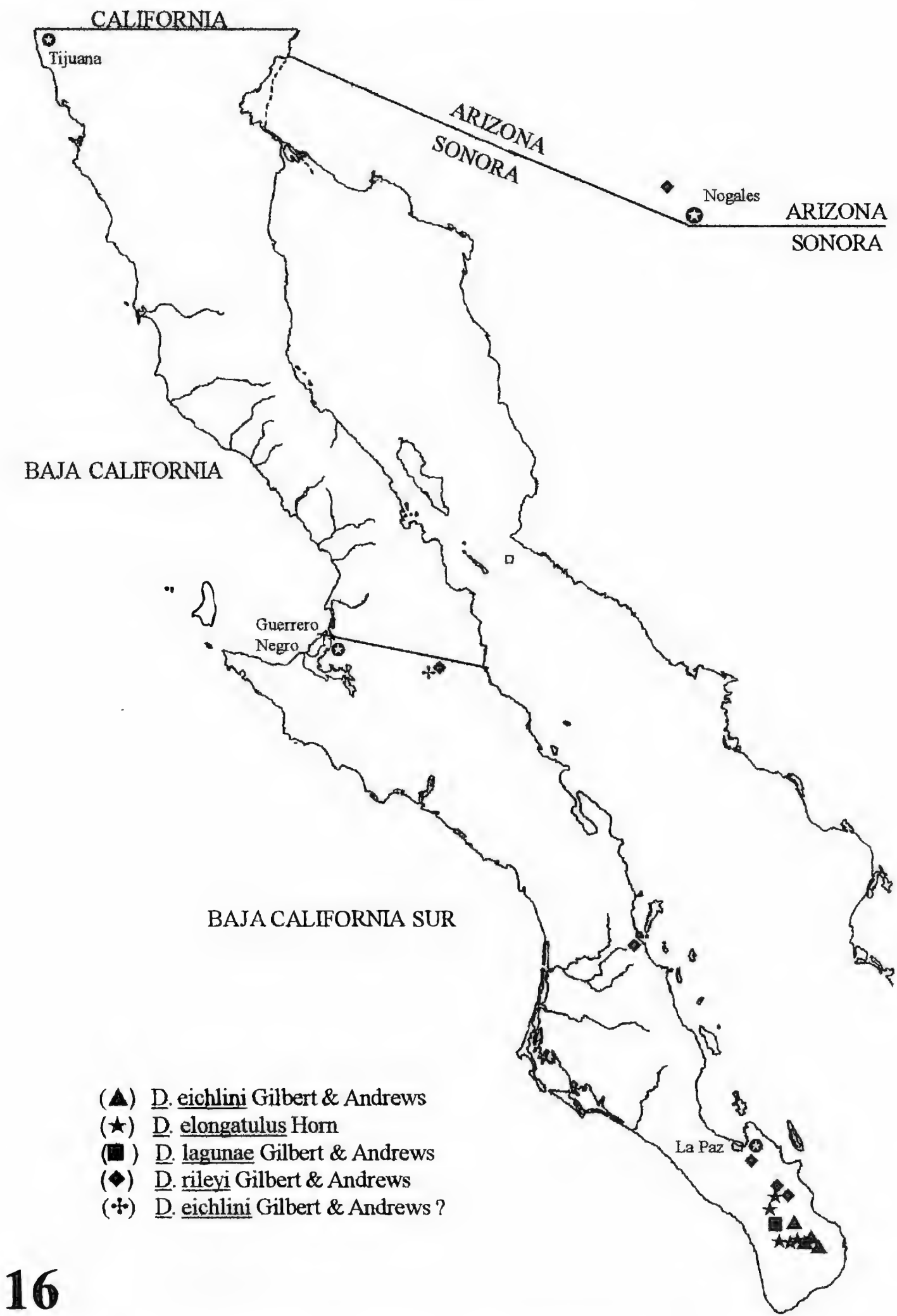
Figures 13–15. Female spermatheca. Figure 13. *D. eichlini*. Figure 14. *D. elongatulus*. Figure 15. *D. rileyi*.

1 on Ramal Sn Antonio de la Sierra, 19 Sep 1988, A. J. Gilbert (1) [AJGC]; Ramal Naranjas Rd., 11.7 km (7.3 mi) W Highway 1, 455 m (1500'), 1 Sep 1990, F. Andrews, T. Eichlin & A. Gilbert (24) [AJGC], (2) [UNAM], (18) [CDFA], (2) [TAMU]; 19.6 km (12.2 mi) SE San Pedrito near Rancho Saucito, 8 Oct 1981, F. Andrews & D. Faulkner, general sweeping (1) [CDFA]; Ramal Naranjas Rd., 30.3 km (18.8 mi) W Highway 1, 606 m (2000'), 2 Sep 1990, Andrews, Eichlin & Gilbert (1) [AJGC]; Ramal Naranjas Rd., 33.6 km (20.9 mi) W Highway 1, 394 m (1300'), 2 Sep 1990, F. Andrews, T. Eichlin & A. Gilbert (1) [AJGC]; 11.6 km (7.2 mi) W on Ramal a Los Naranjas, 15 Sep 1988, E. G. Riley (1) [EGRC]; 6.9 km (4.3 mi) W. hwy 1 on Ramal a El Rosario, 6/7 Sep 1988, E. G. Riley (1) [EGRC]; 13.5 km (8.4 mi) W. on Ramal a Los Naranjas, 13 Sep 1988, E. G. Riley (3) [EGRC]; San Jose del Cabo (2) [MCZC]; Cape San Lucas (1) [MCZC]; Sierra San Lazaro (1) [MCZC].

DYSPHENGES LAGUNAE GILBERT & ANDREWS, NEW SPECIES
(Figs. 6, 11)

Type. Holotype (male) (CASC # 17713): MEXICO. BAJA CALIFORNIA SUR: Sierra La Laguna, 1770–1850 m, 29 Aug 1977, E. Fisher, R. Westcott. Deposited in the California Academy of Sciences.

Description.—Male (holotype). Length 2.00 mm; width at elytral humeri 0.80 mm; form elongate. Color fuscous, except face, antennae and legs lighter to varying degrees. Head with vertex fuscous and face rufotestaceous; vertex indistinctly alutaceous, moderately densely, coarsely punctate; eyes entire; frontal tubercles faintly indicated, smooth, elongate, separated by small pit, merging with interantennal carina; interantennal carina distinct, broad; antennae reaching nearly to center of elytra; antennomeres 1–3 testaceous; antennomeres 4–11 gradually darker; antennomeres 2–3 subequal in length, but shorter than antennomeres 1 and 4–10; antennomere 11 longest. Pronotum 1.2 times wider than long, shining, glabrous, coarsely, densely punctate, with punctures almost as large as those of elytral striae, anterior corners forming acute, laterally projecting tooth; basolateral tooth less acute. Scutellum broad, u-shaped, impunctate, glabrous. Elytra 1.6 times longer than wide, shining, glabrous,



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Figure 16. Known geographical distribution of the described species of *Dysphenges*.

with short scutellar row of punctures and nine complete longitudinal rows of regularly placed coarse punctures (first stria not confused with scutellar row, except a few punctures at union), with most punctures separated by at least diameter of puncture; elytral apex subtruncate with outer angle rounded, inner angle squared; epipleura wide throughout entire length (at least as wide as two elytral intervals at widest portion), with scattered, coarse punctures (larger than those of elytra). Pygidium exposed beyond elytra. Venter sparsely punctate, fuscous (except last ventrite lighter medially); last ventrite with broad, short lobe and dark median, longitudinal line or depression extending length of segment. Legs with femora and tibia dark brown (lighter than rest of body); tarsi testaceous. Genitalia as in Figs. 6 and 11.

Female. Unknown.

Variation.—Only the unique holotype is known.

Diagnosis.—The single specimen from La Laguna is quite distinct. The coarse, uniform punctation of the vertex and frons, the elytral punctures that are mostly large and separated by more than the width of the punctures, and the fuscous to piceous coloration of the entire body will serve to differentiate *D. lagunae* from all other species. Examination of the aedeagus (Figs. 6, 11) will add additional certainty to the identification.

Distribution.—Known only from the La Laguna region of Baja California Sur (Figs. 16–17).

Host.—Unknown.

Etymology.—Named for the unique, high altitude region of the Sierra de La Laguna in the cape region of Baja California Sur.

Material Examined.—See type.

DYSPHENGES RILEYI GILBERT & ANDREWS, NEW SPECIES

(Figs. 1–5, 9, 15, 18–19)

Types.—Holotype (male) (CASC # 17714) and allotype (female): MEXICO. BAJA CALIFORNIA SUR: Ramal a El Rosario, 4.8 km (3.0 mi) S. El Triunfo, 6/7 Sep 1988, A. J. Gilbert; collected from *Mimosa purpurascans* Robinson. Holotype and allotype deposited in the California Academy of Sciences. Paratypes: (50)—same data as holotype and allotype (9) [AJGC], (2) [UNAM]; 2.1 km (1.3 mi) W San Antonio, 487 m (1600'), 31 Aug 1990, F. Andrews, T. Eichlin & A. Gilbert (2) [CDFA]; 6.9 km (4.3 mi) W. hwy. 1 on Ramal a El Rosario, 6/7 Sep 1988, on *Mimosa purpurascans* Robinson (24) [EGRC]; 47.5 km (29.5 mi) S Loreto, 25 Sep 1981, F. Andrews & D. Faulkner (1) [SDCM]; 23.0 km (14.3 mi) S La Paz, 27 Sep 1981, D. Faulkner & F. Andrews (1) [SDCM]; 1.6 km (1.0 mi) NE Guillermo Prieto, 19/20 Jul 1999, 27°48'32"/113°18'31", BL, R. Aalbu & K. Brown (1) [CDFA]; U.S.A. ARIZONA: SANTA CRUZ Co., 31°24.25'N–111°11.30'W, 3.2 km (2.0 mi) E Sycamore Cyn., 2 Aug 1997, A. J. Gilbert (10) [AJGC].

Description.—Male (holotype). Length 2.00 mm; width at elytral humeri 0.80 mm; form elongate. Pronotum and legs rufotestaceous; elytra pale-yellow with irregular, longitudinal, fuscous band along sutural margin, elytral apices and apical half of epipleura. Head entirely rufotestaceous, distinctly alutaceous, uniformly, coarsely punctate; eyes entire; frontal tubercles indistinct, obscured by punctation and irregular surface texture; interantennal carina distinct, broad; interantennal space nearly twice width of space between eye and antennal socket (at narrowest point); antennae extending to nearly middle of elytra; antennomeres 1–3 rufotestaceous; antennomeres 4–11 gradually darker; antennomeres 2–3 subequal in length, shorter than antennomeres 1, and 4–10; antennomeres 4–10 subequal in length, each slightly shorter than antennomere 11. Pronotum 1.3 times wider than long (measured at the center line), indistinctly alutaceous, shining, glabrous, densely, uniformly punctate

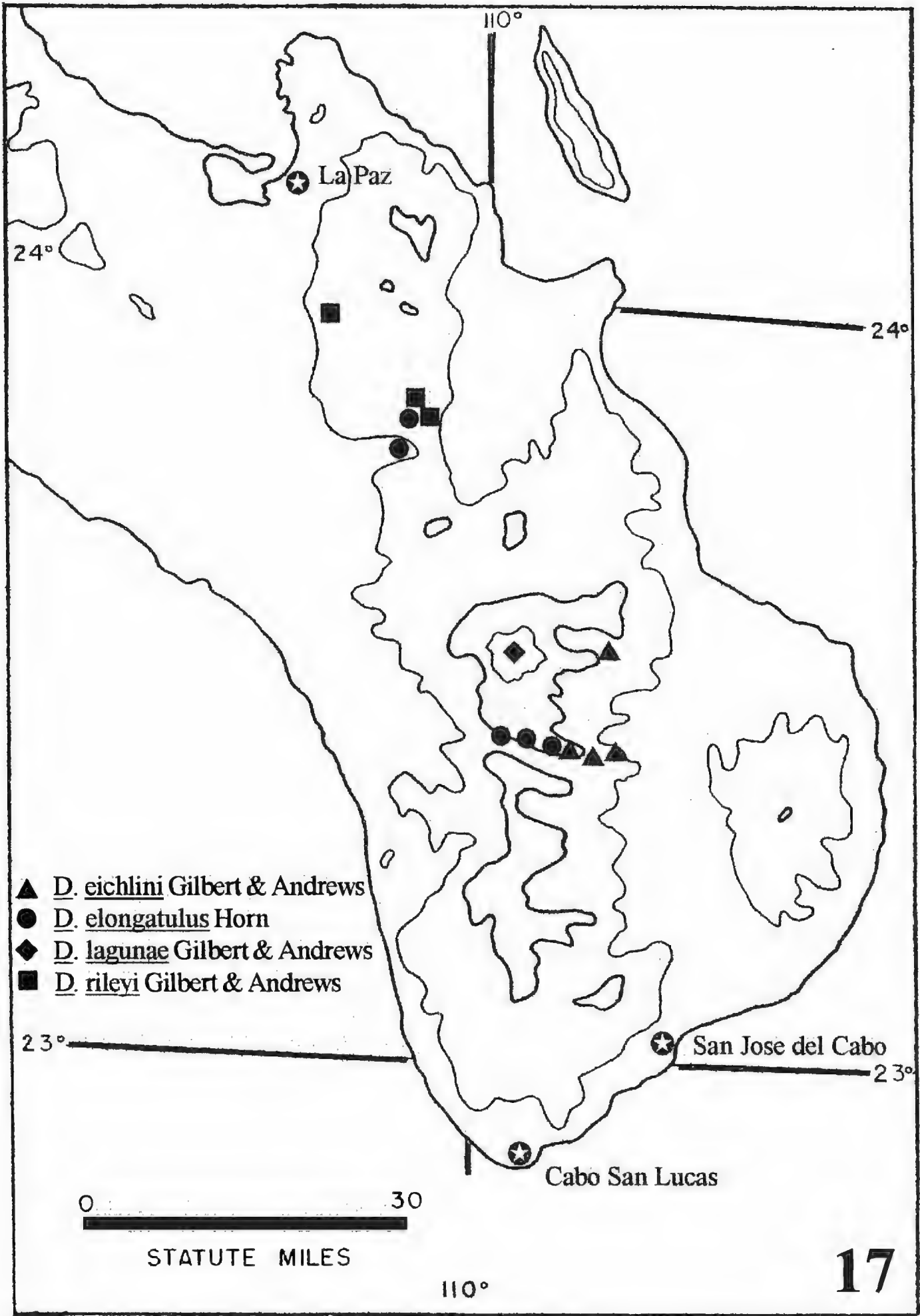
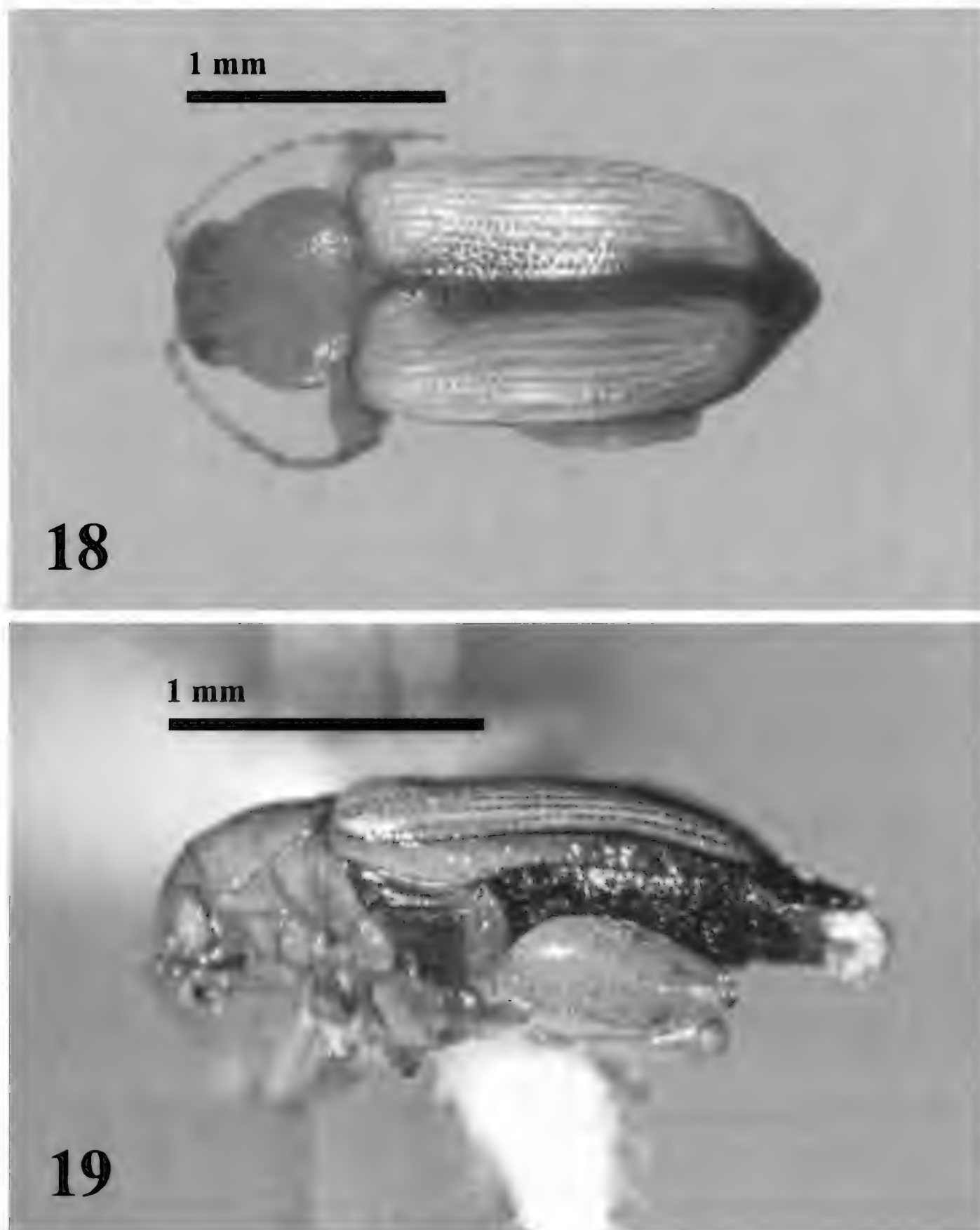


Figure 17. Enlarged view of the cape region distribution of *Dysphenges*.

(punctures equal to those of elytral striae); anterior corners forming laterally projecting tooth. Scutellum rufotestaceous, triangulate, shining, impunctate. Elytra together 1.5 times longer than wide, shining, glabrous, alutaceous with short scutellar row of punctures and nine complete longitudinal rows of regularly placed coarse punctures (most punctures separated by less than diameter of puncture); striae one, two, and scutellar stria confused basally along darkened area of suture; elytral apex sub-

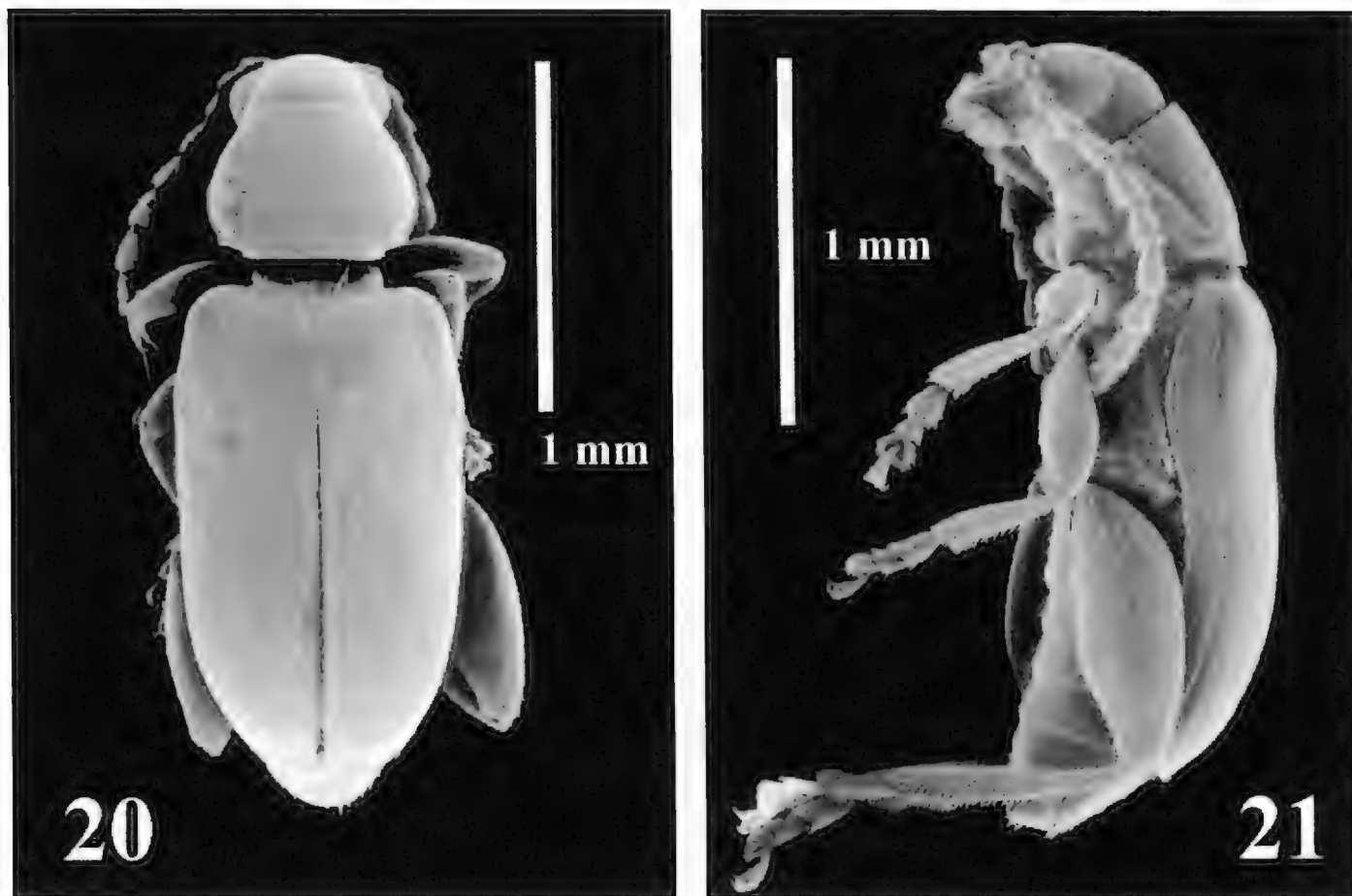


Figures 18–19. Habitus of *D. rileyi*. Figure 18. Dorsal view. Figure 19. Lateral view.

truncate with outer angle rounded, inner angle squared; epipleura rufotestaceous basally, fuscous apically, wide throughout entire length (at least as wide as two elytral intervals at widest point), with scattered, coarse punctures. Pygidium exposed beyond elytra. Venter with metasternum and abdomen fuscous, except medial portion of last ventrite lighter; last ventrite with a broad, short lobe and dark median longitudinal line extending entire length of segment. Legs entirely rufotestaceous. Genitalia as in Figs. 1–5 and 9.

Female (allotype). Similar to holotype, except larger, with length 2.10 mm, width at elytral humeri 0.90 mm: Last ventrite without apical lobe. Spermatheca as in Fig. 15.

Variations.—Male: length 1.95–2.10 mm; width at elytral humeri 0.75–0.85 mm. Female: length 1.80–2.35 mm; width at elytral humeri 0.70–1.10 mm.



Figures 20–21. SEM of *D. elongatulus* Horn. Figure 20. Dorsal view. Figure 21. Lateral view.

Diagnosis.—*Dysphenges rileyi* is the only described species with distinctly bi-colored elytra. The aedeagi are variable, even amongst individuals from a single collection at the same location (Figs. 1–3). Despite this variability, the aedeagi (Figs. 1–5) are generally similar in form and sufficiently different to separate *D. rileyi* from all other described or known undescribed species, including a similarly colored undescribed species from the state of Jalisco, Mexico. The spermatheca of *D. rileyi* is distinct and also somewhat variable (Fig. 15). But it is quite different from the spermathecae of *D. eichlini* (Fig. 13) and *D. elongatulus* (Fig. 14), leaving no doubt as to the validity of the species.

Distribution.—Known from southern Arizona and Baja California Sur (Figs. 16–17). With this distribution, *D. rileyi* probably also occurs in the Mexican states of Baja California and/or Sonora.

Host.—Thirty-seven specimens of the type series from Baja California Sur were collected from *Mimosa purpurascens* Robinson (Fabaceae) (misspelled on the label). *Mimosa purpurascens* is restricted to Baja California Sur south of Mulegé and to the mainland Mexican states of Sonora and Sinaloa (Roberts 1989, Wiggins 1980). The two specimens from northeast of Guillermo Prieto, collected at blacklight, are from an area at the extreme northern part of Baja California Sur, nearly into the state of Baja California, and far north of the reported range of *M. purpurascens*. The Arizona specimens were collected from an unidentified, small, very low-growing *Mimosa* species. *Mimosa purpurascens* can reach three meters in height (Roberts 1989). Most likely, *D. rileyi* utilizes more than one *Mimosa* species, at least as an adult host when the plant is in bloom.

Etymology.—Named for Edward G. Riley for his numerous contributions and dedication to the systematics of Chysomelidae.

Material Examined.—See types.

ACKNOWLEDGMENT

Specimens were made available for this study by Vincent Lee (California Academy of Sciences), Al Newton (Field Museum of Natural History), Philip Perkins (Museum of Comparative Zoology), Dave Faulkner (San Diego County Natural History Museum), Ed Riley (Texas A & M University) and Cheryl Barr (University of California, Berkeley). Also, we extend our appreciation to Edward Riley, Shawn Clark and Alan Hardy who reviewed the manuscript.

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**PARASITISM OF *CYDIA* SPP. (LEPIDOPTERA:
TORTRICIDAE) ON *SOPHORA CHRYSOPHYLLA*
(FABACEAE) ALONG AN ELEVATION GRADIENT OF
DRY SUBALPINE FOREST ON MAUNA KEA, HAWAII**

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Abstract.—The biology and ecological importance of Hawaiian endemic *Cydia* spp. (Lepidoptera: Tortricidae) are poorly known. *Cydia* larvae are an important food to palila, an endangered Hawaiian bird that inhabits *Sophora* woodlands on Mauna Kea, Hawaii. We quantified *Cydia* larval abundance in seeds of *Sophora chrysophylla* Salisbury (Fabaceae) and larval mortality caused by parasitism. Four new host plant associations are reported: *C. crassicornis* [Walsingham], *C. falsifalcella* [Walsingham], *C. obliqua* [Walsingham], and *C. storeella* [Walsingham]. Four parasitoid wasp species were consistently reared from larval *Cydia*: *Calliephialtes grapholithae* [Cresson], *Diadegma blackburni* [Cameron], *Pristomerus hawaiiensis* Perkins (Hymenoptera: Ichneumonidae), and *Euderus metallicus* [Ashmead] (Hymenoptera: Eulophidae). The three Ichneumonidae appear to be accidental introductions, while *E. metallicus* is likely to be native to Hawaii. Parasitism rates by all four wasps combined decreased with elevation from 94% at 1800 m to 20% at 2700 m.

Key Words.—Insecta, *Cydia* spp., parasitism rates, seasonal abundance, Hawaii, alien species.

Cydia Hübner (Lepidoptera: Tortricidae) is a cosmopolitan genus of small moths. *Cydia* species include economic pests such as the codling moth, *C. pomonella* (L.) on apples and the pea moth, *C. nigricana* (Stephens) on legumes, while other *Cydia* species attack fruits, nuts, and cambium of other angiosperms and conifers (Zimmerman 1978). There are fourteen known *Cydia* species endemic to Hawaii that form a closely allied species complex (Walsingham 1907, Zimmerman 1978) with broad variations in colors and wing patterns. All endemic Hawaiian *Cydia* species, with known hosts, are found exclusively on plants in the family Fabaceae including *Acacia koa* A. Gray, *Acacia koaia* Hillebrand, *Canavalia galeata* (Gaudichaud), *Sophora chrysophylla* (Salisbury), and *Strongylodon lucidus* (Seemann). The host plants of six *Cydia* species are not known (Zimmerman 1978). On *Sophora*, three seed-feeding *Cydia* species are known; *C. latifemoris* (Walsingham), *C. montana* (Walsingham), and *C. plicata* (Walsingham) (Swezey 1954). Little is known about the ecology of Hawaiian *Cydia* species, and descriptions of their impact on seed production have been only anecdotal (Swezey, personal communication in Zimmerman 1978).

Three parasitoid species are historically known from *Cydia* larvae (Perkins 1913, Swezey 1954, Zimmerman 1978). *Eupelmus pelodes* Perkins (Hymenoptera: Eupelmidae) is an endemic parasitoid of *C. plicata*; *Trathala flavo-orbitalis* (Cameron) (Hymenoptera: Ichneumonidae) is an accidental alien parasitoid of *C. parapteryx* (Meyrick); and *Pristomerus hawaiiensis* Perkins (Ichneumonidae),

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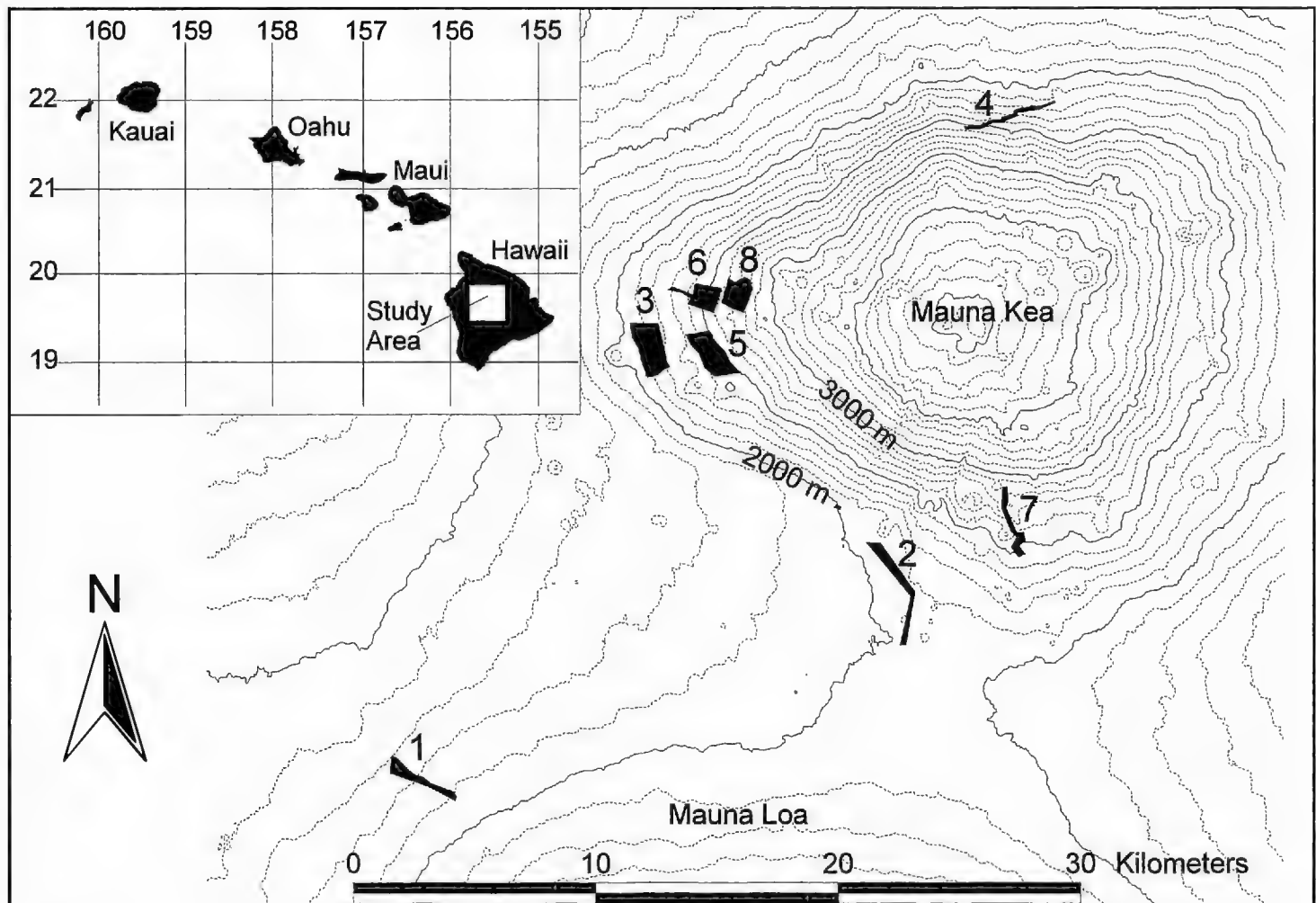


Figure 1. Location of 8 study sites on Mauna Kea and Mauna Loa volcanoes. Inset shows location of study areas on Hawaii Island, Hawaii.

place of origin uncertain, is a parasitoid of *C. conspicua* (Walsingham), *C. plicata*, and *C. walsinghamii* (Butler). The rate of parasitism by these wasps, and their impacts to ecosystems are not known.

Sophora-feeding *Cydia* are the most important insect prey of palila (*Loxioides bailleui* Oustalet), an endangered species of Hawaiian finch (Fringillidae: Drepanidinae) and may represent an important protein source for developing chicks (U.S. Geological Survey, unpublished data). Parasitism by native and alien wasps may be resulting in decreased abundance of *Cydia*. We investigated the seasonal abundance and rate of parasitism of *Sophora*-feeding *Cydia* species along an elevation gradient of dry subalpine forest on Mauna Kea, Hawaii.

MATERIALS AND METHODS

Site Description.—Eight study sites were located from 1700 m to 2850 m elevation on Mauna Kea volcano and the saddle region between Mauna Kea and Mauna Loa, Hawaii Island, Hawaii (Fig. 1). Rainfall averages 511 mm/year at 2260 m elevation on the western slope of Mauna Kea (58-year average, Juvik et al. 1993) and varies slightly with elevation and aspect. Average annual temperature at 2600 m elevation is 11° C, with mean daily maximum temperatures ranging from 15° to 17° C and mean daily minimum ranging from 4° to 9° C (Juvik et al. 1993). The dominant vegetation type at higher elevations is open *Sophora chrysophylla* forest (sites 6, 8), and at lower elevations mixed *Myoporum sandwicense* A. Gray (Myoporaceae)—*Sophora* forest (sites 1–5, 7) (see Hess et al. 1999 for more detailed descriptions). The eight sites generally follow an ele-

Table 1. Abundance, density, and activity of *Cydia* larvae in *Sophora* pods from Feb 1992 to Apr 1997 at 8 sites along an elevation gradient. *Cydia* abundance = # larvae/pod, *Cydia* density = # larvae/ha, *Cydia* activity = Ave # seeds eaten/pod, % Seeds eaten = Ave % seeds eaten/pod.

Site	Ave. elev. (m)	<i>Cydia</i> abundance	<i>Cydia</i> density	<i>Cydia</i> activity	% Seeds eaten	No. of pods (n)
1	1800	0.04	20	0.07	2.4	523
2	2015	0.02	144	0.06	2.0	2244
3	2150	0.09	475	0.20	6.8	2616
4	2325	0.22	1010	0.52	15.5	1736
5	2425	0.13	572	0.27	8.4	3166
6	2450	0.25	4584	0.57	16.4	5418
7	2650	0.23	2287	0.53	16.6	1550
8	2700	0.20	6682	0.54	15.2	5210

vation gradient (Table 1). *Sophora* trees sampled were spaced 150 m apart along transects (except sites 1 and 2, where trees were at random distances 100 to 500 m). Transects within each site were at least 200 m apart.

Cydia Abundance.—Each month from Feb 1992 to Aug 1997 two *Sophora* pods were collected haphazardly and within reach from the ground from each tree being studied. If pods were not available on a study tree, they were collected from the nearest tree with pods. The number of trees sampled varied between sites and in some months pods were not available at all sites (Table 1). Pods were dissected in the laboratory, and the number of seeds eaten and number of *Cydia* larvae present were recorded for each pod.

Parasitism.—Each month from Apr 1996 to Apr 1997 ten additional pods with external evidence of *Cydia* caterpillars inside (approximately 1 mm hole with silk cap) were selected from each study site. Pods were placed individually into 240 ml clear plastic cups and covered with mosquito netting to allow air circulation and prevent molding. Cups were checked daily for the emergence of adult moths or parasitoids. After three months, pods showing no activity were dissected to determine caterpillar occupancy. Live caterpillars were returned to their pods and wrapped with moist paper towels to finish development. Voucher specimens of parasitic Hymenoptera were sent to the Hawaii Department of Agriculture for identification. Tentative identifications were made for species of *Cydia* pending a revision of the genus, therefore, analysis considered all *Cydia* species together.

Analysis.—Parasitism rate was calculated as the percent of *Cydia* larvae that produced a parasitic wasp (*Cydia* larvae that died of unknown causes before adults emerged were not included). Linear regression was used to assess *Cydia* abundance, *Cydia* feeding activity, and parasitism over elevation.

RESULTS

We detected 3969 *Cydia* larvae during dissection of 22,463 pods from February 1992 to August 1997. *Cydia* abundance (number of larvae per pod) followed a yearly cycle, generally peaking in August through October and dropping to a low during April through June (Fig. 2). Average *Cydia* abundance reached a peak of 515 larvae per 1000 pods in October 1992 and a low of 7 larvae per 1000 pods in March 1994, for all sites combined. Peaks in *Cydia* abundance generally oc-

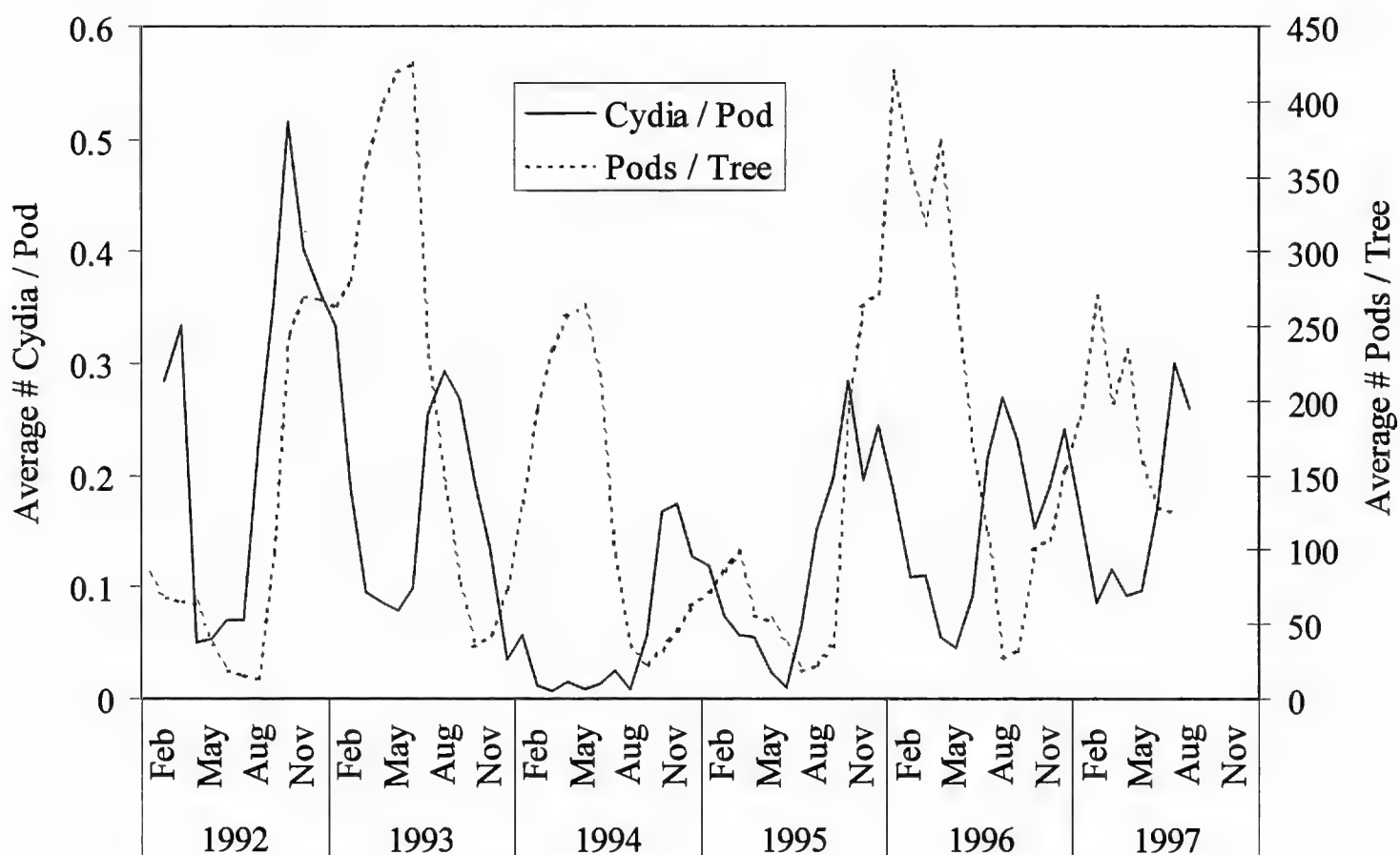


Figure 2. Average number of *Cydia* larvae per pod and average number of pods per tree from Feb 1992 to Aug 1997 for 8 study sites combined.

curred when pods were least available as caterpillars became more concentrated in the few remaining pods.

Cydia density (number of larvae per hectare) generally increased with elevation (Table 1). *Cydia* density was calculated using tree density estimates (Hess et al. 1999), average number of pods per tree (U.S. Geological Survey, unpublished data), and average *Cydia* abundance per pod. *Cydia* activity (number of seeds eaten by *Cydia* per pod) also increased with elevation (Table 1).

Seven *Cydia* species were reared from *Sophora* pods. *C. latifemoris*, *C. montana*, and *C. plicata* were previously known to feed on mamane (Zimmerman 1978), while *C. crassicornis* (Walsingham), *C. falsifalcella* (Walsingham), *C. obliqua* (Walsingham), and *C. storeella* (Walsingham) are new host records. All were previously known from Hawaii Island, except *C. storeella*, which was previously known only from Maui (Nishida 1997).

Cydia moths or their associated parasitoids emerged from 439 pods out of 616 pods collected for rearing from April 1996 to April 1997. Each pod contained one *Cydia* larva, except for 42 pods that contained two larvae, and two pods that contained three larvae. Of the 177 pods from which no insects emerged, larvae in 84 died in the laboratory (possibly from pseudoparasitism (Jones et al. 1986), desiccation, or other unknown causes) and 93 had no larvae when collected (larvae vacated pods before collection or external signs of larvae were misidentified in the field).

Four parasitoid species were reared from pods containing *Cydia* larvae (Table 2). *Pristomerus hawaiiensis* (Ichneumonidae), a solitary endoparasitoid, was the most common (98 wasps total), particularly at lower elevations. *Euderus metallicus* (Ashmead) (Eulophidae), a gregarious ectoparasitoid, was found consistently across elevations. Forty-six parasitized *Cydia* larvae produced 221 *E. metallicus*

Table 2. Parasitism of *Cydia* spp. by 4 wasp species over 8 sites along an elevation gradient (data pooled from Apr 1996 to Apr 1997). % Parasitism (of *Cydia* larvae) for each site is given for each wasp species individually. % Emergence *Cydia* spp indicates the % of *Cydia* larvae that successfully reared to an adult moth.

Site	Elevation average (m)	% Parasitism <i>P. hawaiiensis</i>	% Parasitism <i>E. metallicus</i>	% Parasitism <i>C. grapholithae</i>	% Parasitism <i>D. blackburni</i>	% Emergence <i>Cydia</i> spp.	# Larvae (n)
1	1800	64.7	5.9	23.5	0.0	5.9	17
2	2015	38.9	5.6	44.4	0.0	11.1	18
3	2150	46.9	12.5	3.1	0.0	37.5	32
4	2325	25.0	9.1	9.1	0.0	56.8	44
5	2425	28.6	9.5	9.5	2.4	50.0	84
6	2450	16.5	4.9	1.0	6.7	70.9	103
7	2650	19.1	5.9	5.9	7.3	61.8	68
8	2700	0.0	15.1	0.0	4.7	80.2	126
Total	—	19.9	9.3	6.1	4.1	60.6	492

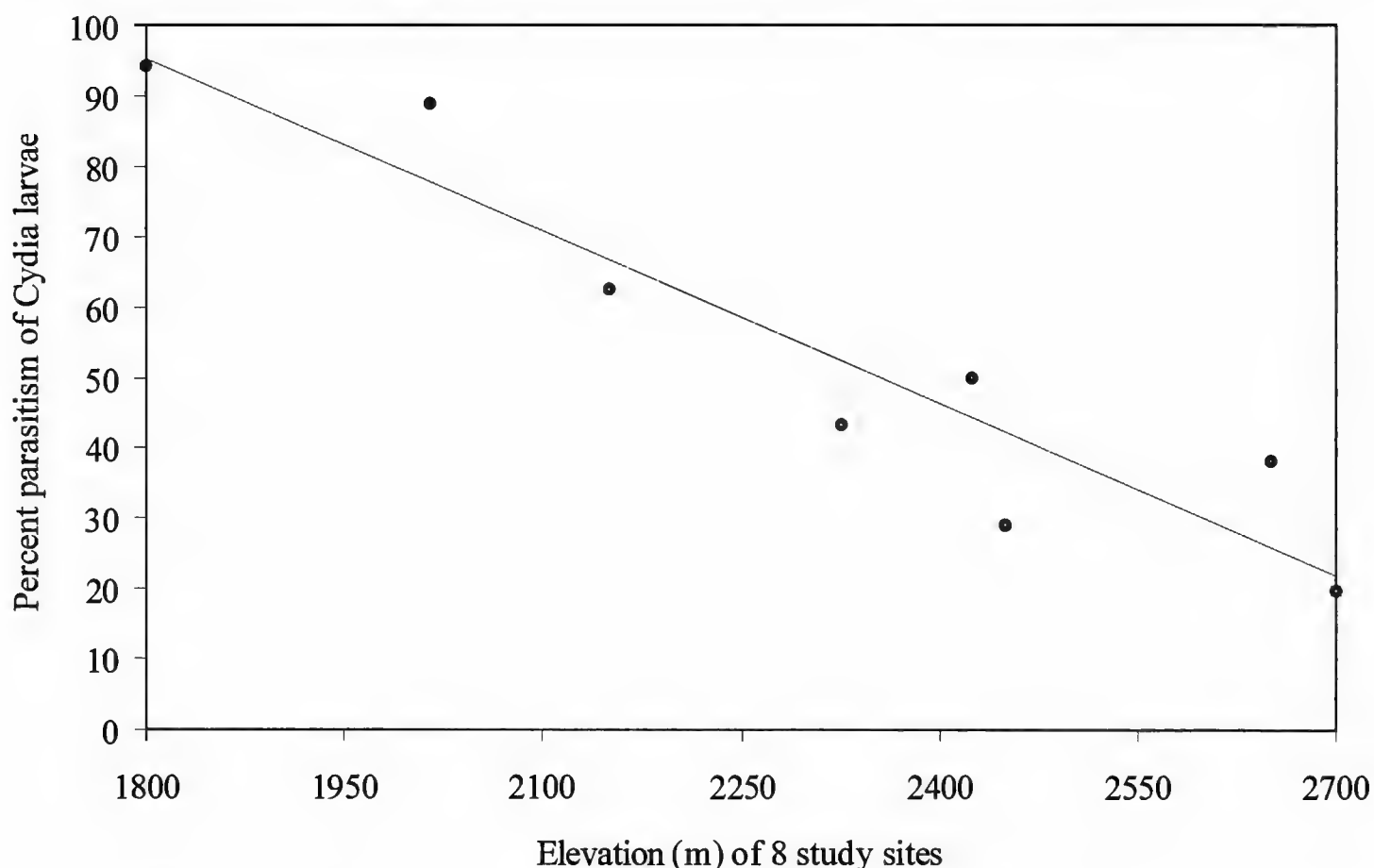


Figure 3. Percent of *Cydia* larvae parasitized by 4 wasp species combined over an elevation gradient (data pooled from Apr 1996 to Apr 1997).

wasps. *Calliephialtes grapholithae* (Cresson) and *Diadegma blackburni* (Cameron) (Ichneumonidae), both solitary endoparasitoids, were less abundant (30 and 20 wasps, respectively). Six other Hymenoptera species, including *Sierola* sp. (Bethyridae), *Anagyrus* sp. (Encyrtidae), *Brasema cushmani* (Crawford) (Eupelmidae), Unidentified sp. (Mymaridae), *Brachyserphus hawaiiensis* (Ashmead) (Proctotrupidae), Unidentified sp. (Trichogrammatidae), and unidentified species of Acari, Anthocoridae, Pseudococcidae, Hemerobiidae, Psocoptera, and Thysanoptera were also recovered from mamane pods. These species occurred infrequently and probably have little impact on *Cydia* populations.

Parasitism rate (percent of larvae parasitized) by all four parasitoid species combined decreased with increasing elevation (Fig. 3). There was strong evidence that the abundance of *Cydia* at each site was influenced by the rate of parasitism ($t = -3.0995$, $P = 0.0269$), after accounting for changes in *Cydia* abundance due to elevation (multiple $r^2 = 0.8663$):

$$\text{Abundance} = 0.8585 - 0.0052(\text{Parasitism rate}) - 0.0001(\text{Elevation}).$$

There was also strong evidence that the percent of *Sophora* seeds consumed by *Cydia* was negatively influenced by the rate of parasitism (multiple $r^2 = 0.8474$):

$$\% \text{ Seeds Eaten} = 22.0331 - 0.2289(\text{Parasitism Rate}).$$

DISCUSSION

Of the fourteen described species of Hawaiian *Cydia* several are known only from one gender and only eight have recorded host plant associations (Zimmerman 1978). One unnamed species (new species 1 in Zimmerman 1978) was witnessed to infest 50 to 75 percent of the crown of several trees of *Acacia koaia*,

boring through twigs and small branches (C. J. Davis, personal communication in Zimmerman 1978). Other species inhabiting *Acacia koa* have been reared from the bark, dead twigs, and seeds of the tree. On *Sophora chrysophylla*, *C. latifemoris* was observed to destroy nearly one-half of a season's seed crop on Maui, while *C. plicata* was found in up to 70% of seeds on Hawaii Island (O. H. Swezey, personal communication in Zimmerman 1978). Tentative identifications in this study suggest the following new associations with *Sophora*: *C. crassicornis*, *C. falsifalcella*, *C. obliqua*, and *C. storeella*, with hosts previously unknown, were reared from *Sophora* seeds. It is unclear, therefore, whether the high infestation rates of *Sophora* seeds previously reported represent an attack by one species or more.

Abundance of *Sophora*-feeding *Cydia* species followed temporal and spatial patterns. Larval abundance, in most years, reached its peak within the late summer (August, September, and October), while reaching its lowest point in the spring (April, May, and June). *Sophora* pods are generally available year round with several peaks occurring throughout the year (U.S. Geological Survey, unpublished data). *Cydia* larval abundance (caterpillars/pod) is most pronounced when pods are scarce and caterpillars become more concentrated in the few remaining pods. This result suggests that larval densities (caterpillars/hectare) may change little throughout the seasons or in response to food decline. Several measures (abundance, density, and feeding activity) indicate that *Cydia* prevalence in pods increased with increasing elevation. Of the two anomalies to this pattern, one site (site 7) covers a broader elevation range than the others, while the second site (site 5) differs in dominant forest type from its neighboring sites. Increase in *Cydia* prevalence with elevation may also be confounded by increased *Sophora* tree density and decreased parasitism over the same elevation gradient.

Overall parasitism rates of *Cydia* decreased with increasing elevation, from 94% at 1800 m to 20% at 2700 m. Individually, however, the ichneumon species showed segregation relative to elevation. Parasitism at lower elevations was dominated by *Pristomerus hawaiiensis* and *Calliephialtes grapholithae*, while *Diadegma blackburni* was discovered only at higher elevation sites. In contrast, parasitism by the eulophid wasp, *Euderus metallicus*, appeared uniform across sites.

The origin of the three Ichneumonidae is under debate, though each is likely alien to Hawaii. It appears unlikely that any of these three wasps were introduced as biological control agents in Hawaii. Although congeners of *D. blackburni* and *P. hawaiiensis* were introduced into Hawaii for the control of lepidopteran pests in 1953 and 1942, respectively (Lai & Funasaki 1986), both species were already present at the turn of the 20th century (Ashmead 1901, Perkins 1910). Furthermore, although collected in Oregon in 1897 (Carlson 1979), *D. blackburni* was originally described from Mauna Kea, Hawaii (Cameron 1883), before formal biological control efforts began in Hawaii. Fullaway & Krauss (1945) suggest *P. hawaiiensis* is an immigrant from the Orient, but give no reasoning for this supposition.

C. grapholithae is an important parasitoid of *Cydia caryana* (Fitch), a major pest of pecans in the southeastern United States (Yonce et al. 1996). And although this wasp is the most common parasitoid of *Cryptophlebia illepidia* (Butler) (Lepidoptera: Tortricidae), a major pest of macadamia nuts in Hawaii (V. P. Jones, unpublished data), neither *C. grapholithae* nor any congeners have been recorded

as purposeful introductions into Hawaii (Lai & Funasaki 1986). However, records of biological control releases were incomplete in the first half of the 20th century when many new species were introduced to the islands (Swezey 1931, Howarth 1991).

The status of *E. metallicus* is also unclear (Nishida 1997). However, it has not been collected outside of the Hawaiian Islands, and may represent an endemic species (J. W. Beardsley, personal communication). Given the ubiquity of this species in our collections, it is curious that this wasp was not previously documented from *Cydia*, while *Eupelmus pelodes*, previously reared from *C. plicata* (Swezey 1954), did not occur in our study.

Sources of *Cydia* mortality, other than these four wasps, remain uncertain. An immigrant ground beetle, *Pristonychus complanatus* Dejean (Coleoptera: Carabidae), and immigrant spiders, *Cheiracanthium diversum* L. Koch (Clubionidae) and *Tegenaria domestica* (Clerck) (Agelenidae) can each be found in *Sophora* trees along with native predators (PTO, personal observation) and may prey on *Cydia* adults. Egg parasitoids, such as *Trichogramma* spp. (Hymenoptera: Trichogrammatidae), have not been investigated for most of Hawaii's native Lepidoptera and may also be a source of *Cydia* mortality.

Hawaiian *Sophora*-feeding *Cydia*, are prey to parasitoids and consumers of endemic seed crops. However, habitat associations and environmental constraints of both native and alien parasitoids require further elucidation to determine factors guiding patterns of parasitism witnessed in this study. Mortality factors, other than parasitism, and basic life histories of *Cydia* species also need to be systematically addressed. Finally, long-term viability of these endemic moth populations needs to be assessed in light of their importance as a food resource to an endangered bird species.

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**TWO NEW SPECIES OF *MICTIS* LEACH
(HETEROPTERA: COREIDAE: MICTINI)
FROM SULAWESI**

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Abstract.—Two new species of *Mictis* from the Sulawesi Islands are described and illustrated.
A key to the known Sulawesi species is included.

Key Words.—Insecta, Hemiptera, Heteroptera, Coreidae, Mictini, *Mictis*, new species, Sulawesi.

The tribe Mictini occurs only in the Eastern Hemisphere and includes 47 genera (Schuh and Slater 1995). O'Shea and Schaefer (1980) reviewed the generic rank of the tribe Mictini to Asia and Australia, and recognized, described, or re-described each of the 19 genera from that region. Drawings of head, pronotum, metathoracic scent gland, hind tibia, abdomen, male genital capsule, paramere, and aedeagus, and a key were given. The genus *Mictis* Leach was diagnosed with 18 species and one subspecies and only *M. profana* (Fabricius) was recorded from Sulawesi (Blöte 1938).

The present paper was prompted by the discovery of two new species of *Mictis* from Sulawesi, based on specimens housed in the Zoologische Staatssammlung, Munchen, Germany.

KEY TO SULAWESIAN *MICTIS*

- 1. Clavus and apical margin of corium yellow, contrasting sharply with the rest of hemelytra to form a cross-shaped pattern *Mictis profana* (Fabricius)
- 1'. Clavus and corium reddish brown with costal border, apical angle and apical border chestnut orange, not forming a cross-shaped pattern 2
- 2. Antennal segments I to III pale orange yellow; humeral angle obtuse; abdominal segment VII laterally expanded; posterior angle of connexival segments without strong conical tubercle; hind tibia dilated on both outer and inner surfaces; hind trochanter of male without apical tubercle (Fig. 2) *Mictis sulawesiana* Brailovsky NEW SPECIES
- 2'. Antennal segments 1 to III black; humeral angle sharply projected laterally; abdominal sternite VII gradually narrowing, not laterally expanded; posterior angle of connexival segments with large and stout conical tubercle; hind tibia with outer surface not dilated, and inner surface with only the distal third expanded; hind trochanter of male with large, robust tubercle (Fig. 1) *Mictis riedeli* Brailovsky NEW SPECIES

MICTIS PROFANA (FABRICIUS)

Lygaeus profanus Fabricius, 1803: 211.

This species is widely distributed throughout Australia, Papua New Guinea,

British Solomon Islands, Sumatra, Flores, Timor, Moluccas, Fiji, Samoa, Amboina, and Sulawesi (Celebes) (Blöte 1938, O'Shea and Schaefer 1980). *Mictis profana* (Fabricius) the only previously known Mictini recorded from Sulawesi, is easily recognized by the yellowish markings forming a cross on the closed hemelytra.

MICTIS RIEDELI BRAILOVSKY, NEW SPECIES

(Fig. 1)

Types.—Holotype male: South Sulawesi. Tanah Toraja, Pulu Pulu, 1700 m, 13–16 Aug 1990, A. Riedel. Deposited in Zoologische Staatssammlung München, Germany. Paratypes: 2 males, 2 females; data: same as holotype. Deposited in the Zoologische Staatssammlung München, Germany and Colección Entomológica del Instituto de Biología, UNAM, México.

Description.—Male (holotype). Dorsal coloration: Head black with jugum, tylus, apical margin of antenniferous tubercle and the space between eye and ocelli dark yellow; antennal segments I to IV black; pronotum bright chestnut orange with calli black; scutellum bright chestnut red with apex yellow; clavus and corium reddish-brown with costal border, apical angle, and apical border dark chestnut orange; hemelytral membrane brown with basal angle black; connexival segments and tubercles yellow; dorsal abdominal segments reddish brown with wide yellow longitudinal stripe running through segments II to VI. Ventral coloration: Head black, with buccula and longitudinal stripe running from antenniferous tubercle to posterior border of head yellow; rostral segments I to III yellow with upper face black, and IV with anterior half yellow and posterior half and upper face black; prothorax and acetabulae black with propleura yellow; mesothorax with acetabulae, mesosternum, and posterior margin of mesopleura black with yellow longitudinal stripe running lateral to mesosternum and mesopleura; metathorax orange yellow with acetabulae, and anterior and posterior border of metasternum black; fore and middle leg with coxa and trochanter yellow, femora and tibia yellow with apical third black, and tarsi black; hind leg with coxa and trochanter including the tubercle black, femur orange yellow with basal joint, and apical third including both spines black, tibia orange yellow with apical third and spine black, and tarsus yellow; pleural abdominal sterna III to VII yellow; abdominal sterna III to VII yellow with two longitudinal stripes lateral to middle third reddish brown; tubercles of abdominal sternite III and rim of abdominal spiracle yellow; genital capsule yellow with inner third reddish brown. *Structure*.—Head: Rostrum reaching middle third of mesosternum. Thorax. Pronotum: Slightly declivent; collar wide; anterolateral border obliquely straight, irregularly spinated or dentate; frontal angles projected forward as conical teeth; humeral angle sharply projecting laterally; posterolateral border sinuate, with upper half nodulose and inner half smooth. Legs: Fore and middle trochanter unarmed; external face of hind trochanter with large and robust tubercle; fore and middle femora relatively slender, ventrally armed with two acute, subapical spines; hind femur markedly incrassate, not attaining the apex of abdomen, reaching at most anterior or middle third of abdominal sternite VI; dorsal and ventral surface minutely tuberculate, ventrally with two large, triangular subapical spines; fore and middle tibia unarmed, sulcate, slightly expanded at posterior third; hind tibia large, recurved, outer surface not dilated and distally with short stout spine, inner surface with distal half expanded, with two spines, the subdistal one large and acute, and the apical one short and stout. Scutellum: Triangular with apex flat. Hemelytra: Macropterous, reaching the apex of last abdominal segment. Abdomen: Gradually narrowing, with abdominal segment VII not laterally expanded; connexival segments sulcate, with upper margin densely and irregularly nodulose and posterior angle of segment III to VI projected on a large and stout conical tubercle; abdominal sternite III armed with a pair of ventrolateral tubercles. Genital capsule: Posteroventral border slightly sinuate at middle third.

Female.—Dorsal coloration: Head black with jugum, tylus, apical margin of antenniferous tubercle and the space between eye and ocelli bright orange red; antennal segments I to III black and IV black with wide orange red ring close to basal third or pale orange yellow with basal joint black, and wide brown ring close to apical third; pronotum bright reddish orange with calli black; scutellum bright reddish orange with apex yellow; clavus reddish-brown with claval vein reddish orange; corium reddish-brown with corial veins, costal border, apical angle, and apical border reddish orange. Ventral coloration: Including legs and rostral segments I to IV bright orange, with following areas black: upper

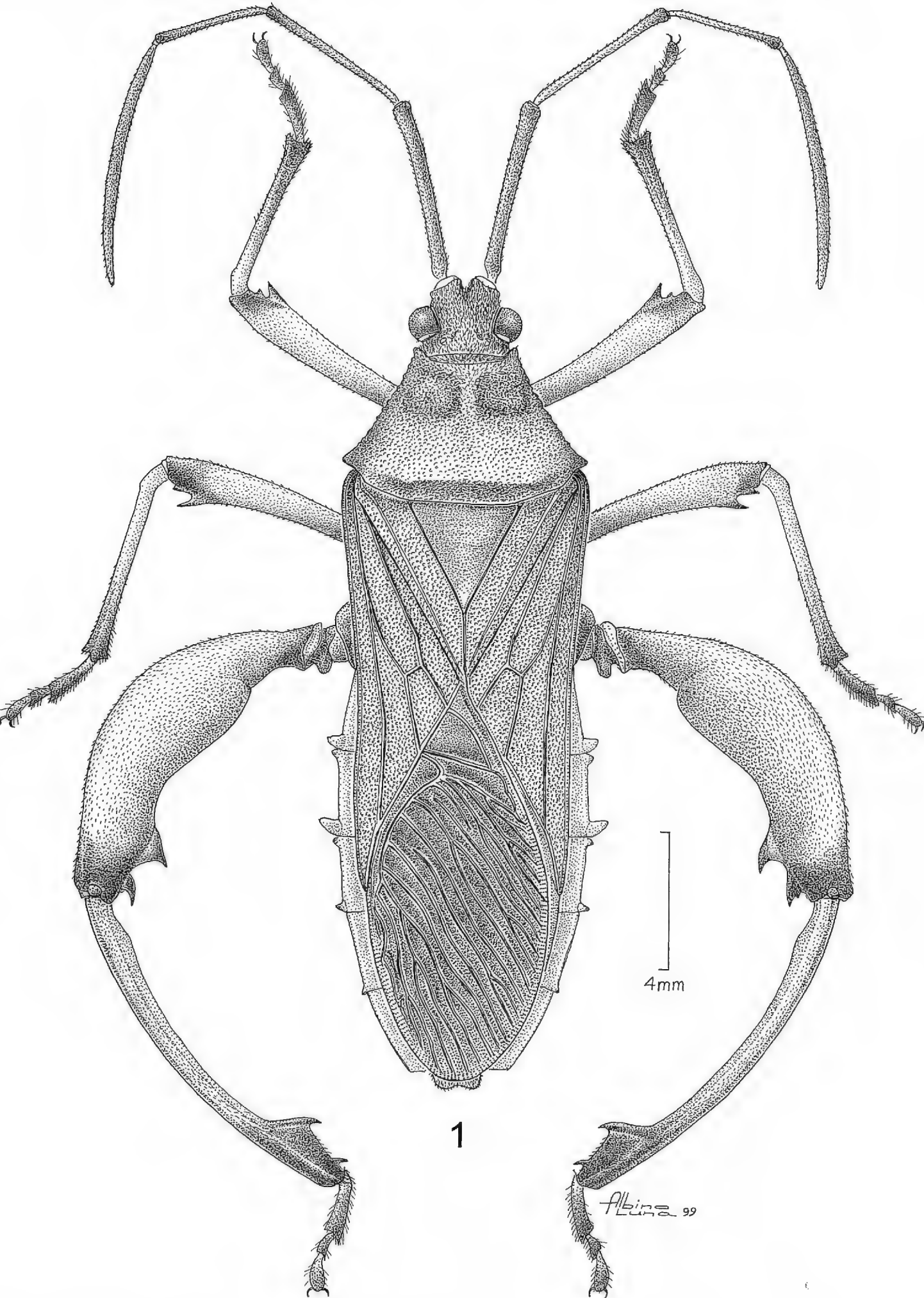


Figure 1. Dorsal view of *Mictis riedeli* Brailovsky, (male).

face of rostral segments I to IV, apical third of rostral segment IV, lateral longitudinal stripes on mesosternum, scattered discoidal spots on mesocoxa, and apical border of tibia; connexival segments III to VII black with anterior margin reddish orange, and segments VIII and IX reddish brown. *Structure*.—Similar to male. Outer face of hind trochanter unarmed; hind femur incrassate (less than male), ventral surface uniseriately spinated from base to apex, with a large trifurcate subapical spine; hind tibia unarmed, sulcate, and slightly expanded at posterior third; connexival segments with upper face minutely nodulose, and posterior angle of segments III to VI with short and stout spine; abdominal sternite VII without lateral tubercles. Genitalia: Abdominal sternite VII with plica and fissura; gonocoxae I enlarged antero-posteriorly, with external face entire; paratergite VIII triangular, with spiracle visible; paratergite IX squarish, larger than paratergite VIII.

Measurements (based on a single specimen).—Male (female). Head length: 1.90 mm (1.84 mm); width across eyes: 2.81 mm (2.60 mm); interocular space: 1.38 mm (1.38 mm); interocellar space: 0.66 mm (0.63 mm); antennal segments lengths: I, 5.09 mm (5.09 mm); II, 4.10 mm (3.80 mm); III, 2.81 mm (2.96 mm); IV, 6.61 mm (6.46 mm). Pronotal length: 4.71 mm (4.63 mm); width across frontal angles: 2.58 mm (2.66 mm); width across humeral angles: 6.98 mm (6.98 mm); Scutellar length: 3.11 mm (2.88 mm); width: 2.96 mm (3.02 mm). Hind femur length: 10.75 mm (8.50 mm). Hind tibia length: 11.00 mm (8.75 mm). Maximum width of abdomen: 7.44 mm (7.62 mm). Total body length: 23.76 mm (22.50 mm).

Discussion.—This species is most similar to *Mictis discolor* Dallas with outer surface of hind tibia not dilated, and inner surface with only the distal third expanded (Fig. 1), and both species lack the middle abdominal tubercle between sterna III and IV.

Mictis riedeli is recognized by the antennal segments I to III black, hind trochanter of male with large and robust tubercle, humeral angles sharply projected laterally, abdominal sternite III with pair of robust ventrolateral tubercles, and posterior angle of connexival segments with large conical tubercle (Fig. 1). In *M. discolor*, recorded from the Philippines, the antennal segments I to III are pale orange yellow, the male hind trochanter blunt without apical tubercle, humeral angles obtuse, abdominal sternite III with sharp tubercle, and the posterior angle of connexival segments without conical tubercle.

Etymology.—Named for Alexander Riedel, collector of the species.

MICTIS SULAWESIANA BRAILOVSKY, NEW SPECIES (Fig. 2)

Types.—Holotype male: Central Sulawesi. Lake Poso, Pendolo, 21 Aug 1990, A. Riedel. Deposited in Zoologische Staatssammlung, Munchen, Germany.

Description.—Male (holotype). Dorsal coloration: Head and pronotum bright chestnut orange; antennal segments I to IV pale orange yellow; scutellum bright chestnut orange with apex yellow; clavus and corium reddish-brown with costal border, and apical angle chestnut orange; hemelytral membrane brown; connexival segments III to V reddish-brown with anterior border yellow; segments VI and VII with anterior half yellow and posterior half reddish-brown; dorsal abdominal segments reddish-brown, and VII reddish-brown with middle third of posterior margin chestnut orange. Ventral coloration: Bright chestnut orange with dark yellow marks irregularly distributed; anterior and posterior lobe of metathoracic peritreme creamy yellow; rostral segments I to IV yellow with apical third of segment IV black; fore and middle leg pale orange yellow; hind leg chestnut to reddish-brown, trochanter pale orange yellow, apex of tibia black, and tarsus pale yellow; mesosternum laterally, hind acetabulae, abdominal sterna IV and V, and lateral tubercles of sternite III dark reddish-brown; rim of abdominal spiracle yellow. *Structure*.—Head: Rostrum reaching middle third of metasternum. Thorax. Pronotum: Frontal angle with short conical teeth; humeral angle rounded, not expanded laterally; anterolateral border straight, irregularly spinated; posterolateral border sinuate, with upper half spinated and inner half smooth. Legs: External face of hind trochanter blunt, without tubercle; fore and middle femora relatively slender, armed ventrally with two subapical spines; hind femur markedly incrassate, reaching

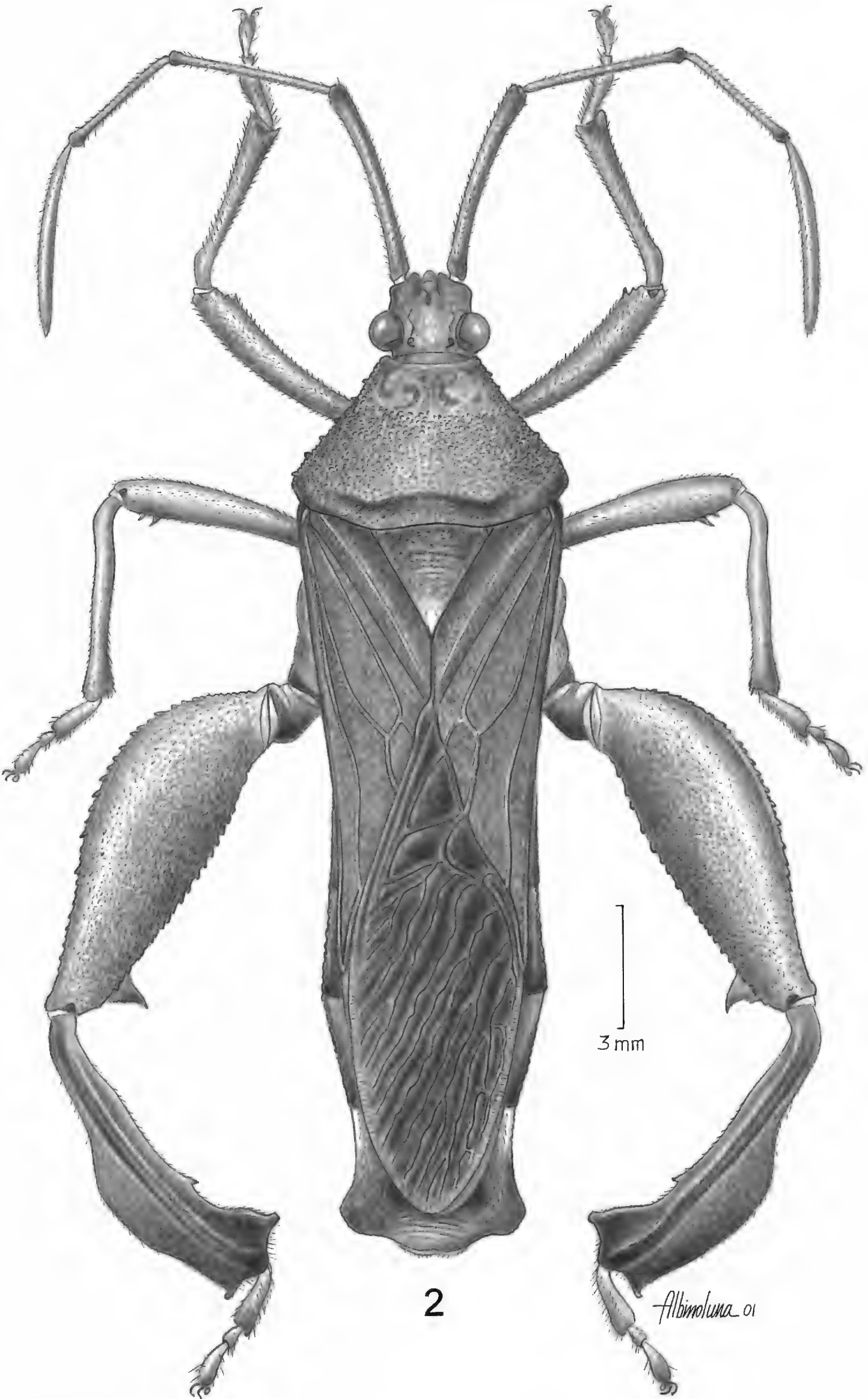


Figure 2. Dorsal view of *Mictis sulawesiana* Brailovsky, (male).

at most anterior or middle third of abdominal sternite VI, and with dorsal and ventral surface minutely tuberculate; dorsal surface uniseriately spinated from base to apex, and ventrally strongly granulated on one irregular row, with a large triangular subapical spine; fore and middle tibiae unarmed, sulcate, and slightly expanded at posterior third; hind tibia recurved, flattened, shorter than femora, with outer surface markedly expanded and apically armed with a subacute spine, and inner surface expanded with two spines, the subapical spine short and acute, and the apical spine robust. Scutellum: Triangular, with apex flat. Hemelytra: Macropterous, almost reaching apex of last abdominal segment. Abdomen: Connexival segments sulcate, with upper margin densely and irregularly denticulate; abdominal segment VII laterally expanded; abdominal sternite III laterally armed with single, stout tubercle; posterior margin of abdominal sternite V slightly elevated. Genital capsule: Posteroventral edge with small concavity at middle third.

Measurements.—Holotype male. Head length: 1.74 mm; width across eyes: 2.73 mm; interocular space: 1.52 mm; interocellar space: 0.69 mm; antennal segments lengths: I, 4.86 mm; II, 4.02 mm; III, 3.26 mm; IV, 4.56 mm. Pronotal length: 4.25 mm; width across frontal angles: 2.35 mm; width across humeral angles: 6.46 mm. Scutellar length: 2.66 mm; width: 2.88 mm. Hind femur length: 9.37 mm. Hind tibia length: 8.25 mm. Maximum width of abdomen: 5.47 mm. Total body length: 24.15 mm.

Female.—Unknown.

Discussion.—*Mictis sulawesiana* is related to *M. riedeli* and recognized by having the abdominal segment VII laterally expanded, antennal segments I to III pale orange yellow, outer and inner surface of hind tibia dilated (Fig. 2), male hind trochanter blunt without apical tubercle, posterior angle of connexival segments serrate without strong conical tubercles, and humeral angles obtuse. In *Mictis riedeli*, the abdomen is gradually narrowed with abdominal segment VII not laterally expanded, antennal segments I to III black, hind tibia with only the inner third expanded (Fig. 1), male hind trochanter with apical tubercle, posterior angle of connexival segments with large conical tubercle, and humeral angles angulate.

Etymology.—Named for its occurrence in the Sulawesi Islands.

ACKNOWLEDGMENT

I thank Klaus Schönitzer (Zoologische Staatssammlung, Munchen, Germany) for the loan of specimens, and Albino Luna (Instituto de Biología, Universidad Nacional Autónoma de México) for the preparation of illustrations.

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A NEW SPECIES OF THE SPIDER GENUS *MACROTHELE* FROM THE GAOLIGONG MOUNTAINS, YUNNAN, CHINA (ARANEAE: HEXATHELIDAE)

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Abstract.—A new species of mygalomorph spider, *Macrothele yani* NEW SPECIES, is described from the Gaoligong Mountains, Yunnan Province, China.

Key words.—Arachnida, Araneae, Hexathelidae, *Macrothele*, NEW SPECIES, taxonomy, Gaoligong Mountains, Yunnan, China.

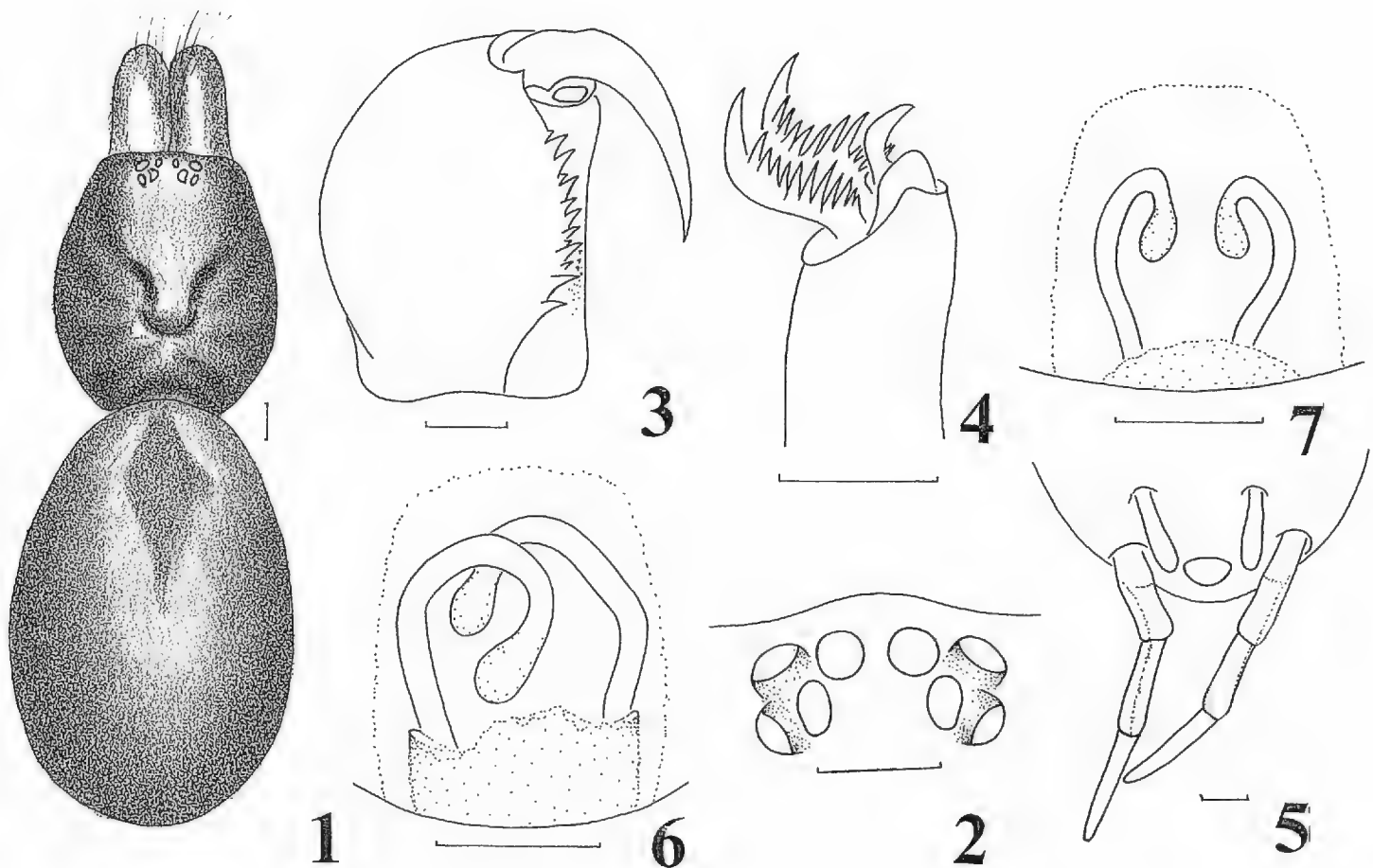
The Hexathelidae were elevated to family rank by Raven (1980). This group of mygalomorph spiders is characterized by the presence of numerous labial cuspules. At present, the family Hexathelidae consists of 11 genera (Song et al. 1999). Only six hexathelid species, all *Macrothele*, have been recorded from China: *M. palpator* Pocock 1901 by Pocock (1901), Hu and Li (1986) and Feng (1990); *M. holsti* Pocock 1901 by Pocock (1901) and Shimojana and Haupt (1998); *M. simplicata* (Saito 1933) by Saito (1933) and Lee (1964); *M. guizhouensis* Hu and Li 1986 by Hu and Li (1986); *M. taiwanensis* Shimojana and Haupt 1998 by Shimojana and Haupt (1998); and *M. monocirculata* Xu and Yin 2000 by Xu and Yin (2000). *Macrothele* is characterized by having the posterior sternal sigilla much larger than the anterior and the chelicerae with only a row of teeth on the promargin or with only an additional row of smaller teeth on retromargin (Raven 1980).

We describe a new species from China, *Macrothele yani* NEW SPECIES. The specimens were collected by the second Sino-American expedition to the Gaoligong Mountains in June and July of 2000. This is contribution number 19 from the California Academy of Sciences (CaAS) Center for Biodiversity Research and Information (CBRI) and contribution number 13 from the China Natural History Project (CNHP).

Measurements are in mm. Abbreviations used are as follows: AER = anterior eye row, AL = abdomen length, ALE = anterior lateral eye, AME = anterior median eye, AME-AME = interval between AME and AME, AME-ALE = interval between AME and ALE, AW = abdomen width, CL = carapace length, CW = carapace width, MOQ = median ocular quadrangle width, MOQA = MOQ anterior, OQA = ocular quadrangle anterior, OQP = ocular quadrangle posterior, PER = posterior eye row, PLE = posterior lateral eye, PME = posterior median eye, PME-PME = interval between PME and PME, PME-PLE = interval between PME and PLE, TL = total length.

MACROTHELE YANI XU, YIN AND GRISWOLD, NEW SPECIES
(Figs. 1–7)

Types.—Holotype, female: CHINA. YUNNAN PROVINCE. FUGONG COUNTY. Gaoligong Mountains, Fugong, 26°32' N, 98°31' E, elev. 1150 meters,



Macrothele yani sp. nov.

Figures. 1–6. *Macrothele yani* NEW SPECIES. 1. Body, dorsal. 2. Eyes, dorsal. 3. Chelicera, median. 4. Tarsal claw of leg. 5. Spinnerets, ventral. 6. Female receptacula. 7. Subadult female receptacula. Scale bars: 1, 2, 3, 5, 6 = 1.00; 4, 7 = 0.5.

24 July 2000, collected by Yan Hengmei; deposited in the College of Life Science, Hunan Normal University (HNU).

Description.—Female: Carapace brown, covered with white hairs. Thoracic groove obvious (Fig. 1). Head region slightly elevated. Eyes in a compact group (Fig. 2). AER almost straight and PER recurved. Eye region width (1.69) greater than twice its length (0.77). Fovea semicircular and deep. Radial grooves obscure. Lateral margins of thoracic region dark, with long dark hairs. Sternum brown, covered with dark hairs and with three pairs of sigillae. Chelicera dark brown. Base of fang with short, minute depression on dorsal side. Chelicera with thirteen promarginal teeth (the first, fourth and ninth smaller) and several very small retromarginal teeth (Fig. 3). Labium wider than long, yellow-brown and with numerous cuspules. Maxillae yellow-brown, with black cuspules on inner angle. Palp and legs brown. Tarsal claw of palp with a single pectinate row of teeth. Legs with three tarsal claws, upper claws with 11 pectinate teeth in a single row (Fig. 4). Tarsus of leg I with 14 ventral rough bristles in regular double rows, metatarsus with double rows of 4–5 bristles, tibia with 4 ventral bristles (one median, three apical). Tarsus of leg II with 10 or 12 bristles in regular ventral double rows, metatarsus with 7 ventral bristles (double rows of 3–4 bristles) and one prolateral, tibia with 3 ventral bristles (one median and two apical) and one prolateral. Abdomen oval, gray-brown and with cardiac pattern slightly darker, reaching from anterior to middle. Two pairs of spinnerets. Anterior spinnerets wider distally than at base. First and second segments of posterior spinnerets with longitudinal ventral ridge in the middle, apical segment of posterior spinnerets digitiform (Fig. 5). Initial part of receptaculum oval and connected to vulva by strongly bent receptive tube, basal tube covered by membrane (Fig. 6). In subadult stage, bending of receptive tube also pronounced (Fig. 7). Individual variation: left and right tube intersecting or not.

Measurements.—Holotype female: TL (19.77), CL (7.77), CW (6.63), AL (11.66), AW (8.23), ALE (0.43), AME (0.37), AME-AME (0.17), AME-ALE (0.11), PLE (0.37), PLE-ALE (0.11), PME (0.40),

PME-PME (0.71), PME-PLE (0.09), MOQ length (0.74) < width, OQA (0.86) < width OQP (1.17).
Leg formula: 4123.

Measurements of legs are as follows:

	Femur	Patella + Tibia	Metatarsus	Tarsus	Total
I	5.49	7.31	4.06	2.29	19.15
II	5.03	7.14	4.00	2.40	18.57
III	4.69	6.29	4.57	2.17	17.72
IV	5.83	7.89	6.06	2.86	22.64

Male.—Unknown

Diagnosis.—We have compared the new species with the six other species of *Macrothele* from China. *M. yani* NEW SPECIES is most similar to *M. holsti* but differs as follows: 1) the receptacular tube of *M. yani* is strongly bent towards the middle and base (Fig. 6), but that of *M. holsti* is only slightly bent laterally; 2) the abdomen of *M. holsti* has five pairs of darker oblique, transverse bands extending from a darker dorsomedian line, while that of *M. yani* has only a darker cardiac pattern (Fig. 1); 3) the sternum of *M. yani* has three pairs of sigillae, but that of *M. holsti* only two pairs (Shimojana & Haupt 1998).

Etymology.—The new species is named after Professor Heng-mei Yan, who collected the type specimen.

Natural History.—*Macrothele yani* were collected in sheet webs on shady embankments along roads and trails, surrounded by weedy vegetation.

Additional Material Examined.—CHINA. YUNNAN PROVINCE. GONGSHAN COUNTY. Gaoligong Mountains, Bingzhongluo, 28°01' N, 98°22' E, elev. 1800 meters, 7 July 2000, 1 subadult female, collected by Yan Hengmei (HNU).

Distribution.—China (Yunnan).

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RELATIVE AND SEASONAL ABUNDANCE OF WOOD BORERS (BUPRESTIDAE, CERAMBYCIDAE) AND CUCUJIDAE TRAPPED IN DOUGLAS-FIR BEETLE PHEROMONE-BAITED TRAPS IN NORTHERN IDAHO

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Abstract.—Wood borers (Buprestidae, Cerambycidae) and flat bark beetles (Cucujidae) were captured in multiple-funnel traps baited with *Dendroctonus pseudotsugae* Hopkins pheromones in two locations in northern Idaho from May to August, 1997. Captured beetles were identified to species and seasonal abundance was described for the most common species. A total of 43 species of beetles were found throughout the study period. One area had higher species richness and total abundance of beetles than the other. Buprestids were most abundant late in the summer (August–September), while cerambycids exhibited both early (May–June) and late (August) season peaks in abundance. Cucujidae flight occurred early in the summer (May–June), which coincided with *D. pseudotsugae* flight. Seventy-two percent of wood borers that were captured are known to be associated with Douglas-fir.

Keywords.—Insecta, Buprestidae, Cerambycidae, Cucujidae, seasonal abundance, pheromones.

The Douglas-fir beetle (DFB), *Dendroctonus pseudotsugae* Hopkins, is found throughout the western United States and Canada where it usually breeds in weakened or freshly killed Douglas-fir, *Pseudotsugae menziesii* (Mirbel) Franco. Although endemic populations persist mostly in dead and damaged trees, epidemic populations attack and kill large numbers of healthy, live trees. Pheromones of DFB are well known (Pitman & Vité 1970, Kinzer et al. 1971, Furniss et al. 1972, Rudinsky et al. 1974, Libbey et al. 1983) and several have been implemented in management strategies (McGregor et al. 1984, Ross & Daterman 1994, Ross & Daterman 1995a).

Bark beetles have large assemblages of associated arthropods (Dixon & Payne 1979, Dahlsten & Stephen 1974, Stephen & Dahlsten 1976) and many of these insects respond kairomonally to bark beetle pheromones (Vité & Williamson 1970, Camors & Payne 1972, Billings & Cameron 1984, Lindgren 1992, Poland & Borden 1997, Allison et al. 2001). In addition, many forest insects respond to host volatiles including terpenes and ethanol (Fatzinger et al. 1987; Chénier & Philogène 1989, Phillips et al. 1988, Schroeder & Lindelöw 1988, Byers 1992). The use of semiochemicals in bark beetle trapping studies provides an opportunity to survey associated forest insects and document species occurrence, relative abundance, and seasonal activity.

Wood boring beetles in the families Buprestidae and Cerambycidae feed in the phloem and/or sapwood of dead, dying, or injured trees, and shrubs (Furniss & Carolin 1977). Many species of wood boring beetles are caught in DFB pheromone-baited traps. Buprestids and cerambycids are ecologically important insect species, contributing to the breakdown of woody debris and nutrient cycling (Furniss & Carolin 1977, Edmonds & Eglitis 1989). In addition to their role in ecological processes, cerambycids compete with and reduce survival of several economically important bark beetle species (Coulson et al. 1976, 1980, Schroeder &

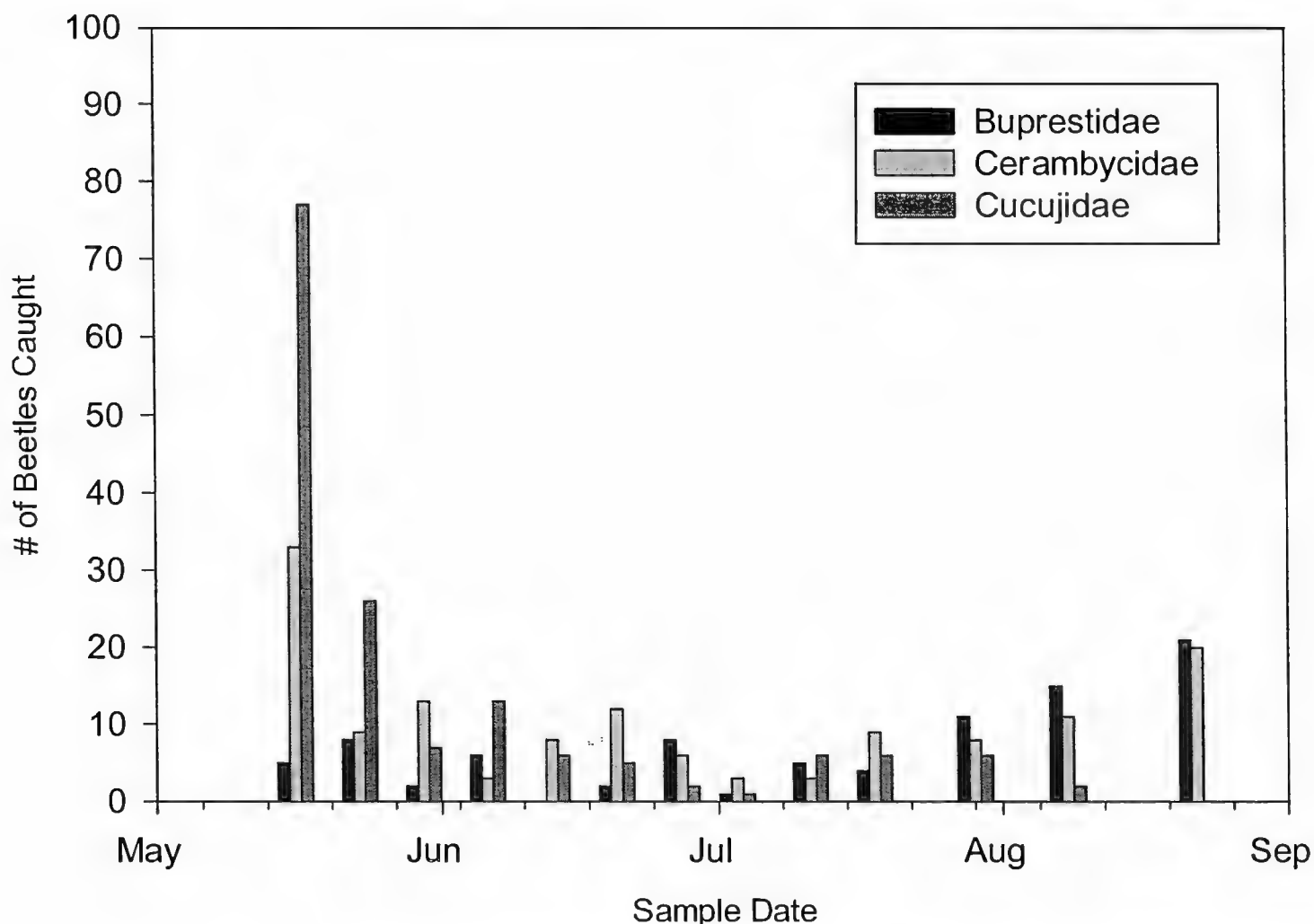


Figure 1. Beetles captured in 27 multiple-funnel traps baited with Douglas-fir beetle pheromones at Fenn, 1997.

Weslien 1994, Dodds et al. 2001, Allison et al. 2001). Although buprestids and cerambycids are ecologically important insects, they also cause significant economic damage to valuable standing trees, and felled or stored logs (Webb 1909, Parmelee 1941, Linsley 1959).

In addition to woodborers, beetles in the family Cucujidae are often collected in pheromone-baited traps. These beetles are typically found under the bark of trees or logs infested by bark beetles (Furniss & Carolin 1977). *Cucujus clavipes* Fabricius is a cucujid found throughout the northern United States that may feed on larvae of bark beetles and associated insect species beneath the bark of host trees (Bedard 1938, Furniss & Carolin 1977).

Little is known about the distribution, abundance, and seasonal activity of Buprestidae, Cerambycidae, and Cucujidae in northern Idaho. The objective of this study was to identify the species of Cerambycidae, Buprestidae, and Cucujidae found in traps baited with DFB pheromones and host volatiles in northern Idaho and describe their seasonal flight patterns and relative abundance.

MATERIALS AND METHODS

The data reported here was part of a larger study to test the efficacy of mass-trapping for DFB. Two areas in the Nezperce National Forest in northern Idaho were sampled from mid-May to late August 1997. These areas, referred to as Fenn and Slate, were approximately 70 km apart and contained similar types of mixed conifer stands. The most common tree species in addition to Douglas-fir were grand fir, *Abies grandis* Lind., western red cedar, *Thuja plicata* Donn., pon-

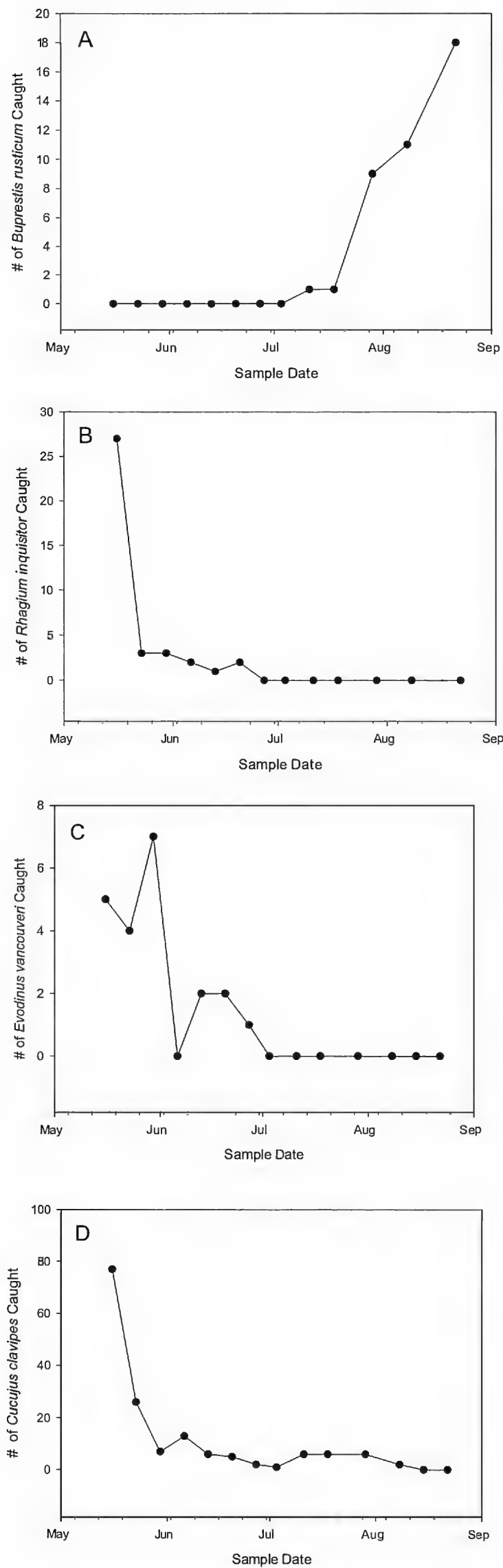


Table 1. Buprestidae caught in 27 multiple-funnel traps baited with Douglas-fir beetle pheromones at Fenn, 1997.

Species	No. caught	% of catch
<i>Buprestis rusticum</i> Leconte	40	44.4
<i>Buprestis aurulenta</i> Linn	11	12.2
<i>Anthaxia inornata</i> Randell	11	12.2
<i>Chalcophora angulicollis</i> (LeConte)	10	11.1
<i>Dicera tenebrosa</i> Kirby	8	8.9
<i>Melanophila drummondi</i> (Kirby)	7	7.8
<i>Trachykele nimbosa</i> Fall	2	2.2
<i>Buprestis nuttalli</i> Kirby	1	1.1
Total number caught	90	

derosa pine, *Pinus ponderosa* Laws, lodgepole pine, *Pinus contorta* Dougl., and Englemann spruce, *Picea engelmanni* Parry ex Engelm. At Fenn elevations ranged from 488 to 732 m, while at Slate elevations ranged from 848 to 1494 m.

Sixteen-unit multiple-funnel traps (Lindgren 1983) baited with polyvinylchloride formulations (Daterman 1974) of frontalin, 1,5-dimethyl-6,8-dioxabicyclo [3.2.1] octane, (400 mg, release rate of 20 mg/day at 24° C) and seudenol, 3-methylcyclohex-2-en-1-ol, (200 mg, release rate of 10 mg/day at 24° C) were placed throughout each area keeping them as far as possible (50–150 m) from mature Douglas-fir trees. In addition, a plastic pouch containing 15 ml of ethanol (Phero Tech Inc., Delta, BC, Canada) releasing at 88 mg/d at 24° C was attached to each trap. Chemical purities and enatiomeric composition for the pheromones were as follows: frontalin 82% pure, 50/50 enatiomeric composition; seudenol 99% pure, 50/50 enatiomeric composition; and ethanol 98% pure. The attractant mixtures and release rates used in this study were optimal for trapping *D. pseudotsugae* (Ross & Daterman 1995b, 1998). A piece of dichlorvos-impregnated plastic was added to each collection cup to kill captured insects. A total of 31 pheromone-baited traps were located at Slate and 27 at Fenn.

Insects captured in pheromone-baited traps were usually collected every 7 to 10 days from 16 May to 22 Aug at Fenn and from 15 May to 26 Aug at Slate. However, no insects were collected at Fenn during the week of 15 Aug. Consequently, the trap collections that occurred on 22 Aug represented a 14 day period. Insects were removed from funnel traps and placed in plastic bags for transfer to the laboratory. In the lab, all *D. pseudotsugae*, and 3 predators, *Thanasimus undatulus* (Say), *Enoclerus sphegeus* Fabricius, and *Temochila chlorodia* (Mannerheim) were removed from samples for use in the larger study. All insects, excluding DFB and the three predators, were returned to sample bags and stored in a freezer. For this study, all Cerambycidae, Buprestidae, and Cucujidae were removed from sample bags and identified to the species level. All insect identifi-

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Figure 2. Seasonal abundance of the buprestid *Buprestis rusticum* (A), the cerambycids *Rhagium inquisitor* (B) and *Evodinus vancouveri* (C), and the cucujid *Cucujus clavipes* (D) captured in 27 multiple-funnel traps baited with Douglas-fir beetle pheromones at Fenn, 1997.

Table 2. Cerambycidae caught in 27 multiple-funnel traps baited with Douglas-fir beetle pheromones at Fenn, 1997.

Species	No. caught	% of catch
<i>Rhagium inquisitor</i> (Linnaeus)	40	29.2
<i>Evodinus vancouveri</i> Casey	21	15.3
<i>Strictoleptura canadensis cribripennis</i> (LeConte)	18	13.1
<i>Leptura obliterata</i> (Haldeman)	11	8.0
<i>Centrodera spurca</i> (LeConte)	9	6.6
<i>Xylotrechus longitarsis</i> Casey	8	5.8
<i>Monochamus scutellatus oregonensis</i> (LeConte)	7	5.1
<i>Anoplodera aspera</i> (LeConte)	5	3.6
<i>Megasemum asperum</i> (LeConte)	4	2.9
<i>Poliaenus oregonus</i> (LeConte)	3	2.2
<i>Anoplodera crassipes</i> LeConte	3	2.2
<i>Holopleura marginata</i> LeConte	2	1.5
<i>Xylocrius agassizi</i> (LeConte)	1	0.7
<i>Atimia dorsalis</i> (LeConte)	1	0.7
<i>Phymatodes dimidiatus</i> (Kirby)	1	0.7
<i>Anoplodera sanguinea</i> LeConte	1	0.7
<i>Neoclytus muricatulus</i> (Kirby)	1	0.7
<i>Xestoleptura tibialis</i> (LeConte)	1	0.7
Total number caught	137	

cations were conducted by K. J. Dodds. Seasonal abundance was described for the most common species occurring at each area.

RESULTS

Three hundred and eighty-four specimens of Buprestidae, Cerambycidae, and Cucujidae were caught at Fenn throughout the sampling period (Fig. 1). A total of 90 Buprestidae representing 8 species were caught in traps at Fenn (Table 1). *Buprestis rusticum* LeConte was the most abundant species accounting for 44.4% of all buprestid catches in the area. Three species, *Chalcophora angulicollis* (LeConte), *Anthaxia inornata* Randell, and *Buprestis aurulenta* Linn were the only others comprising more than 10% of the total catch. *Buprestis rusticum* was not caught before 9 July, but was common from then until the end of the sampling period (Fig. 2A).

Eighteen species of Cerambycidae were caught in traps at Fenn during the study period (Table 2). *Rhagium inquisitor* (Linnaeus) was the most abundant species, comprising 29.2% of the 137 individuals caught. *Evodinus vancouveri* Casey and *Strictoleptura canadensis cribripennis* LeConte were the only other species that comprised more than 10% of the total catch. *Rhagium inquisitor* was abundant early in the trapping season, but numbers dropped significantly after May (Fig. 2B). No *R. inquisitor* were caught after mid-June. *Evodinus vancouveri* catches were also highest in May, with no individuals caught after 25 June (Fig. 2C).

A total of 157 *Cucujus clavipes* were caught at Fenn. *Cucujus clavipes* was prevalent in May, but numbers were low for the rest of the sampling period (Fig. 2D).

Five hundred and sixteen specimens of Buprestidae, Cerambycidae, and Cucujidae were caught at Slate throughout the sampling period (Fig. 3). Twelve

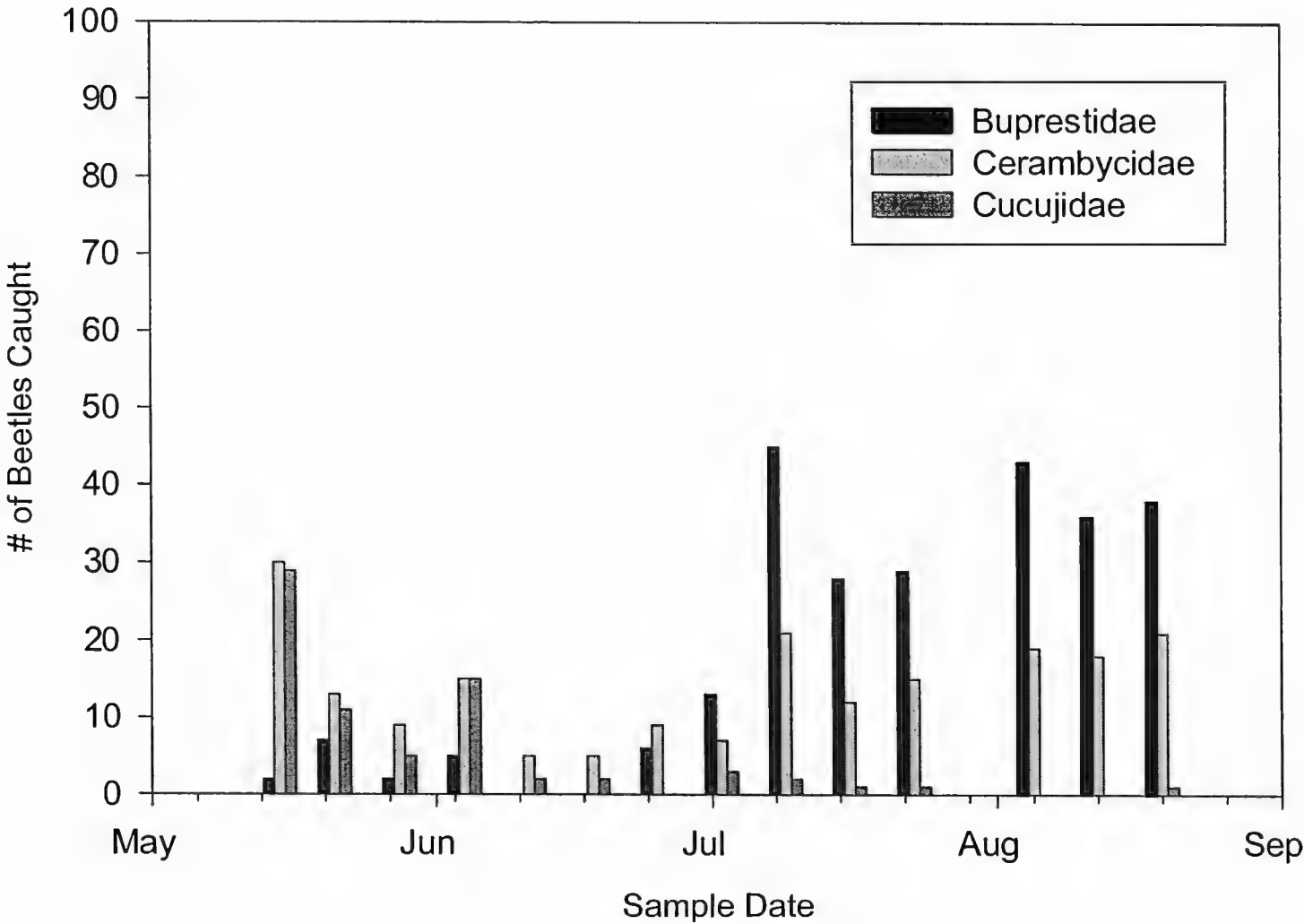
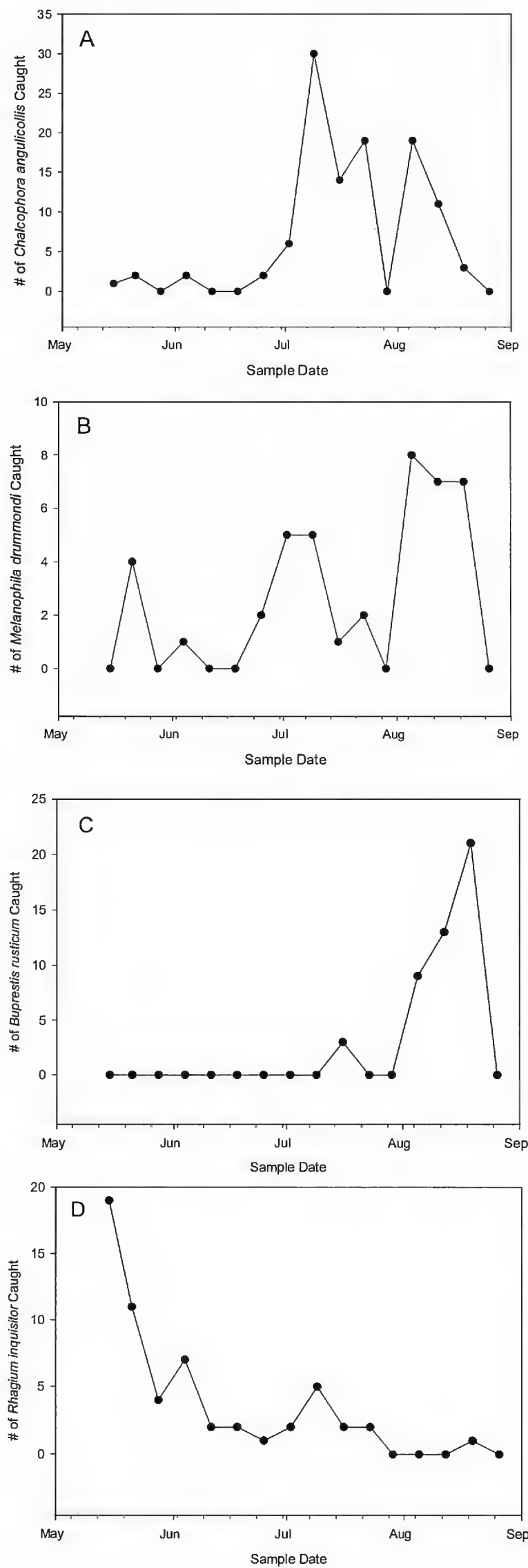


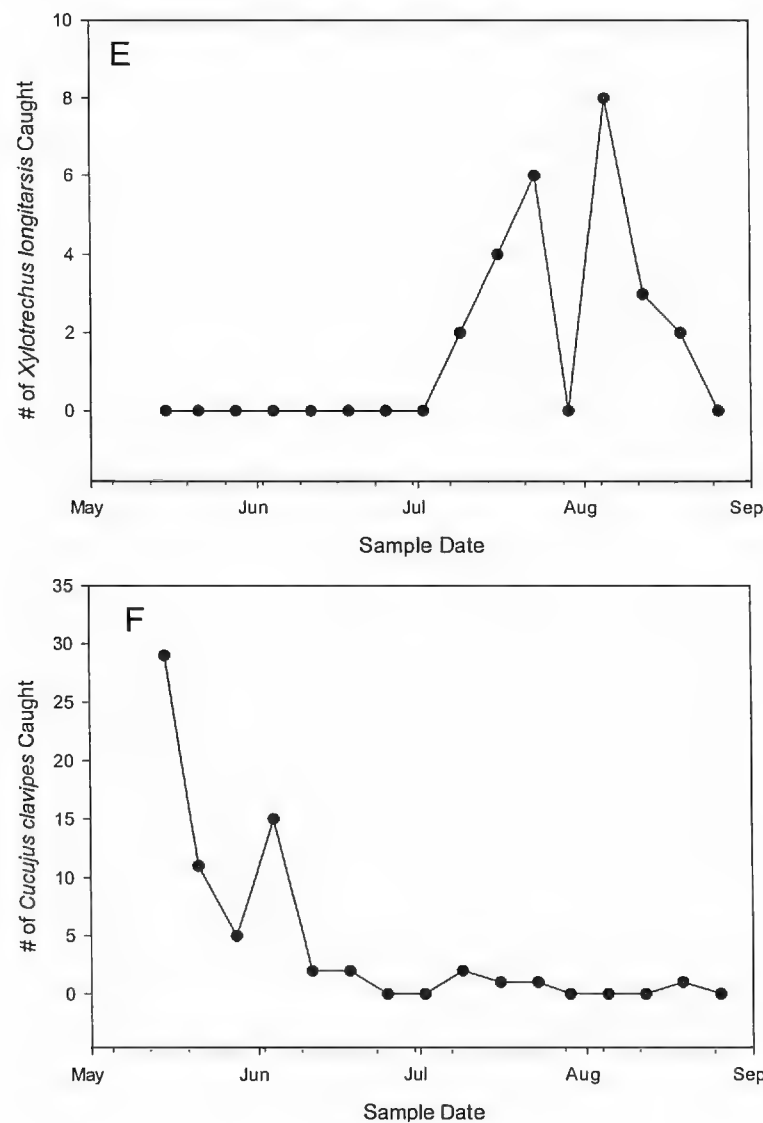
Figure 3. Beetles captured in 31 multiple-funnel traps baited with Douglas-fir beetle pheromones at Slate, 1997.

species of Buprestidae were caught in traps located at Slate (Table 3). Three species, *Chalcophora angulicollis*, *Melanophila drummondi* (Kirby), and *Buprestis rusticum* accounted for over 75% of the 247 buprestids captured. *Chalcophora angulicollis* were most abundant in July and August (Fig. 4A). *Melanophila drummondi* was present throughout most of the sampling period, with highest abun-

Table 3. Buprestidae caught in 31 multiple-funnel traps baited with Douglas-fir beetle pheromones at Slate, 1997.

Species	No. caught	% of catch
<i>Chalcophora angulicollis</i> LeConte	107	43.1
<i>Buprestis rusticum</i> (LeConte)	46	18.5
<i>Melanophila drummondi</i> Kirby	42	16.9
<i>Dicerca tenebrosa</i> (Kirby)	19	7.7
<i>Buprestis aurulenta</i> Linn	12	4.8
<i>Melanophila lecontei</i> Obenberger	8	3.2
<i>Buprestis adjecta</i> Leconte	4	1.6
<i>Anthaxia inornata</i> Randell	3	1.2
<i>Chrysobothris carinipennis</i> LeConte	2	0.8
<i>Chrysophana placida</i> LeConte	2	0.8
<i>Buprestis nuttalli</i> Kirby	1	0.4
<i>Buprestis subornata</i> LeConte	1	0.4
Total number caught	247	





dance occurring in August (Fig. 4B). No *B. rusticum* were caught before mid-July, and numbers increased sharply through August (Fig. 4C).

Two hundred cerambycids representing 25 species were caught at Slate (Table 4). *Rhagium inquisitor* and *Xylotrechus longitarsis* Casey were the most abundant species caught, together comprising 41.5% of the total. The twelve least common species accounted for 11% of the total catch of cerambycids at Slate. The highest abundance of *R. inquisitor* occurred in May, with very few individuals caught in any other month (Fig. 4D). In contrast, *Xylotrechus longitarsis* did not appear in samples until July, with numbers increasing into August (Fig. 4E).

A total of 69 *Cucujus clavipes* were caught at Slate. Trap catches of *C. clavipes* were high in May and dropped to low numbers in June and remained low for the remainder of the sampling period (Fig. 4F).

DISCUSSION

Traps baited with frontalin, seudenol, and ethanol were effective at capturing a large number of phloem/xylem inhabiting insects in the study areas in addition

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Figure 4. Seasonal abundance of the buprestids *Chalcophora angulicollis* (A), *Melanophila drummondii* (B), and *Buprestis rusticum* (C), the cerambycids *Rhagium inquisitor* (D) and *Xylotrechus longitarsis* (E), and the cucujid *Cucujus clavipes* (F) captured in 31 multiple-funnel traps baited with Douglas-fir beetle pheromones at Slate, 1997.

Table 4. Cerambycidae caught in 31 multiple-funnel traps baited with Douglas-fir beetle pheromones at Slate, 1997.

Species	No. caught	% of catch
<i>Rhagium inquisitor</i> (Linnaeus)	58	29.0
<i>Xylotrechus longitarsis</i> Casey	25	12.5
<i>Megasemum asperum</i> (LeConte)	19	9.5
<i>Strictoleptura canadensis cribripennis</i> (LeConte)	14	7.0
<i>Spondylis upiformis</i> Mannerheim	13	6.5
<i>Monochamus scutellatus oregonensis</i> (LeConte)	11	5.5
<i>Anoplodera aspera</i> (LeConte)	8	4.0
<i>Anoplodera nigrella</i> Say	6	3.0
<i>Leptura oblitterata</i> (Haldeman)	6	3.0
<i>Asemum striatum</i> (Linnaeus)	5	2.5
<i>Phymatodes dimidiatus</i> (Kirby)	5	2.5
<i>Monochamus clamator latus</i> Casey	4	2.0
<i>Anthophilax mirificus</i> Bland	4	2.0
<i>Centrodera spurca</i> (LeConte)	3	1.5
<i>Evodinus vancouveri</i> Casey	3	1.5
<i>Gnathacmaeops pratensis</i> (Laicharting)	3	1.5
<i>Callidium pseudotsugae</i> Fisher	2	1.0
<i>Xylocrius agassizi</i> (LeConte)	2	1.0
<i>Neoclytus muricatus</i> (Kirby)	2	1.0
<i>Anoplodera chrysocoma</i> Kirby	2	1.0
<i>Anoplodera sanguinea</i> LeConte	1	0.5
<i>Monochamus obtusus obtusus</i> Casey	1	0.5
<i>Poliaenus oregonus</i> (LeConte)	1	0.5
<i>Tragosoma depsarius</i> (Linnaeus)	1	0.5
<i>Acanthocinus obliquus</i> (LeConte)	1	0.5
Total number caught	200	

to the target insect, *D. pseudotsugae*. Because all of the traps were baited identically during the study period, effects of chemical components on insects could not be determined. However, trap catches document the occurrence of species in the study areas and illustrate the seasonal activity of some species. Ethanol is attractive to many forest insects (Fatzinger et al. 1987; Chénier & Philogène 1989; Phillips et al. 1988; Schroeder & Lindelöw 1988; Byers 1992) and was likely responsible for luring the majority of captured beetles to traps.

Species richness and total abundance of buprestids was highest at Slate, with almost three times as many buprestids caught there compared to Fenn. *Chalcophora angulicollis* and *Melanophila drummondi* were 10 and 6 times more abundant, respectively, at Slate. However, abundance of *B. rusticum* was similar at both study areas. In both areas, total numbers of buprestids tended to increase throughout the summer, with highest numbers occurring in July and August.

Similarly, cerambycid numbers were higher at Slate compared to Fenn, although the differences were not as great as for the buprestids. In addition, species richness of cerambycids was also higher at Slate. In both areas, the cerambycid *R. inquisitor* was the most abundant species comprising 29% of cerambycid catches. Other than *R. inquisitor*, the most abundant cerambycids captured in each area were of different species. Trap catches were relatively low for most species of cerambycids in both areas, with more than 10 individuals collected for only six

species at Slate and four at Fenn. Cerambycids in both areas exhibited similar seasonal activity. Abundance of cerambycids was high in spring, early and late summer, with low numbers occurring in July.

Cucujus clavipes was caught predominantly in May, with similar seasonal trends found in both areas. Because high numbers of *C. clavipes* were caught the first week of trapping it is likely their flight period began before the onset of trapping for this study. Seasonal flight activity of *C. clavipes* corresponds to the initial flight period of DFB. Bedard (1938) listed *C. clavipes* as a predator present on the bark surface of trees newly attacked by DFB. While no definitive evidence exists demonstrating that *C. clavipes* is a predator of DFB, the timing of flight and attraction to semiochemicals known to be attractants for DFB suggests a close relationship between these species. Further research should address the chemical ecology of *C. clavipes* and their role as predators of DFB.

Forty-two species of woodborers were captured in the pheromone-baited traps. Of these 42 species, life history information was gathered from published literature for 40 species. Twenty-nine (72.5%) of these species have been found in association with Douglas-fir (Linsley 1962a, 1962b, 1963, 1964; Linsley & Chemsak 1972, 1976, 1984; Hatch 1971; Kimmey & Funiss 1943). Depending on arrival times and feeding areas, phloem inhabiting species that utilize Douglas-fir may be competitors or predators of DFB. Consequently, some wood borers may contribute to DFB mortality and help to regulate population levels. Similar interactions have been demonstrated between cerambycids and other bark beetle species (Coulson et al. 1976, 1980; Schroeder & Weslien 1994; Dodds et al. 2001; Allison et al. 2001). Further research will be needed to determine the relationships among wood boring beetles, flat bark beetles, and the Douglas-fir beetle.

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LARVAL AND PUPAL BIOLOGY OF A NEW SUN MOTH IN SOUTHERN CALIFORNIA; NOVEL HOST USE STRATEGY IN THE EVOLUTION OF HELIODINIDAE (LEPIDOPTERA: YPONOMEUTOIDEA)

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Abstract.—The biology of immatures of an undescribed heliodinid moth, *Embola powelli*, NEW SPECIES (type locality: California, San Diego County), was studied in southern California. The name *Embola* Walsingham was resurrected from synonymy to accommodate this new moth. As is true of an allied species, '*Heliodines*' *ionis* Clarke, the larva feeds as a stem borer. Modifications in larval behavior and morphology of the pupa are associated with the obligate endophagous life style. In contrast, the only heliodinid outside of *Embola* with larval stem-boring behavior is *Lamprolophus lithella* Busck, which does not show morphological modifications in response to the borer life style and should be regarded as a facultative borer. Consequently, obligate endophagous behavior is considered a uniquely derived feature specific to the *Embola* lineage in the evolutionary history of Heliodinidae.

Key Words.—Insecta, *Embola*, immatures, larval stem borer behavior, evolutionary history, *Mirabilis*, Nyctaginaceae.

Until recently the immature biology and host plant associations of the Heliodinidae were poorly understood (Powell 1980), with larval hosts recorded for only 11 species prior to 1990. Documentation of such information increased considerably in the past decade, with information for 7 species published between 1991 through 1995 (Floater 1995, Harrison & Passoa 1995, Heppner & Landry 1994, Powell 1991). Biologies of 14 additional species were documented during my studies (Hsu 1995). Even with a limited number of species recorded, the immatures of heliodinid moths manifest diverse, species-specific host use strategies. Larvae of all known Old World groups are external feeders (Diakonoff & Arita 1979, Fal'kovich 1990, Floater 1995, Hsu & Powell in press), while heliodinids in the New World employ a variety of feeding behaviors, including leaf skeletonizing, leaf mining, and stem boring (Busck 1900, Harrison & Passoa 1995, Wester 1956). Each of four heliodinid species occurring sympatrically in Illinois has a specific micro-niche on a shared host plant, *Mirabilis nyctaginea* (Nyctaginaceae) (Harrison & Passoa 1995). Of the known feeding strategies, stem boring has been least reported, with just two species, namely, *Lamprolophus lithella* Busck (Busck 1900) and '*Heliodines*' *ionis* Clarke (Harrison & Passoa 1995, Wester 1956). A phylogenetic analysis of the relationships among heliodinid lineages indicated these two moths to be distantly related, with the latter species in a genus of more than 10 species of North American heliodinid moths (Hsu 1995, Hsu & Powell in press). The question of concern here is whether the evolution of stem boring in *Heliodinidae* is a derived feature, and if it arose more than once in the evolutionary history of this moth family.

During surveys on the immature biology of heliodinid moths in southern California, another stem-boring species was recognized from *Mirabilis* species. The moths represent an undescribed species with morphology similar to '*H.* *ionis*.

The species is described here with a discussion given to the significance of the endophagous behavior in terms of heliodinid evolution. Hsu & Powell (in press) pointed out that *ionis* and the other species with similar features in venation and genitalia, including the species described here, are morphologically and phylogenetically distinct from *Heliodines*, a genus based on the Old World species *H. roesella* Linnaeus. Consequently the generic name *Embola* Walsingham, a genus based upon Mexican species with general characters like *ionis* is employed in this paper. *Embola* was synonymized with *Lamprolophus* Busck by Meyrick (1914), but the two genera are not closely related, and *Embola* is resurrected herein.

METHODS AND MATERIALS

Dissections and Measurements.—Genitalic preparations follow those of Brown and Powell (1991) with slight modification. The abdomen is removed by applying slight pressure to the venter using a probe and is placed in a solution of 10% KOH for about 24 hours. Then the abdomen is transferred to water. After initial cleaning, the abdomen is placed in cellusolve for another 24 hours. The abdomen is then transferred to 50% ethanol for further cleaning. For females, a longitudinal incision is made along the left pleuron. The genital capsule is then removed from the pelt by tearing the A6-7 intersegmental membrane for females, and by pulling using a probe with bent tip for males. The abdominal integument and genital capsule then are stained in a weak solution of chlorazol black. Valvae of the male are spread in xylene for position fixing. All parts are slide-mounted in Canada balsam.

Measurements of genitalia parts were taken as follows: length of socii was taken from the base to the apex; length of tegumen was taken excluding the socii; length of saccus was taken as the distance from the distal tip to the junction of saccus with tegumen.

Scanning Electric Microscope Preparation.—Specimens were glued onto a solid aluminum cylinder with silver paint. Glued samples were sputter-coated with two 30 nm layers of gold (Polaron, SEM coating system). Sputter-coated samples were examined using an ISI DS-130 SEM at 10–15 KV.

Descriptions.—Terms for genital characters follow Klots (1970).

Spots on forewing are numbered from the base toward the apex. Abbreviation are as follows: FW = forewing; HW = hindwing; C = costal; D = dorsal; A = abdominal. Color names used in the descriptions are those proposed by Smithe (1975).

Rearing Procedures.—The rearing lot data was recorded employing the year-month-collection larval record system (Brown & Powell 1991). The records are deposited in the Essig Museum of Entomology, University of California, Berkeley, and are summarized in an Access database.

Large collections of larvae (>10 larvae) were placed in plastic bags with double paper towel beneath the vegetation containing immatures for rearing. Small collections (<10 larvae) were placed in plastic vials with tissue paper for rearing.

Some larvae and pupae were preserved in hot water and stored in 70% ethanol. Some pupal shells were saved for examination by SEM.

Type Depositions.—The type series are deposited in the following institutions:

CNC—Canadian National Collection, Agriculture Canada, Biosystematics Re-



Fig. 1. Holotype male of *Embola powelli*.

search Centre, K. W. Neatby Bldg., C.E.F. Ottawa, Ontario K1A OC6, Canada

LACM—Natural History Museum of Los Angeles County, 900 Exposition Boulevard, Los Angeles, California 90007, U.S.A.

NTNU—Department of Biology, National Taiwan Normal University, Taipei, Taiwan 116, R.O.C.

SDNHM—San Diego Natural History Museum, San Diego, California 92112, U.S.A.

UCB—Essig Museum of Entomology, University of California, Berkeley, California 94720, U.S.A.

USNM—Department of Entomology, Entomology, U.S. National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20560, U.S.A.

EMBOLA

Embola Walsingham 1909: 3, REVISED STATUS

Type Species—*Embola xanthocephala* Walsingham 1909, by monotypy

Diagnosis.—*Embola* is characterized by very long and slender saccus, phallus and ductus bursae (Hsu 1995, Hsu & Powell in press). The other genera with similar genital features have flattened antennae, while *Embola* possesses cylindrical antennae. There is a row of long, bristle-like scales behind eyes. Corpus bursae has double signa, one dorsally immediate anterior to the junction with ductus bursae, the other on ventral wall.

EMBOLA POWELLI HSU, NEW SPECIES

(Figs. 1–3)

Types.—Holotype, male: USA. CALIFORNIA, SAN DIEGO Co.: 2 mi (3 km) NE of Lakeside, 400' (122 m), 16 March 1994, reared from *Mirabilis californica*, emgd. 18 April 1994, JAP 94C54 (Y. F. Hsu, H. H. Chuah, UCB)

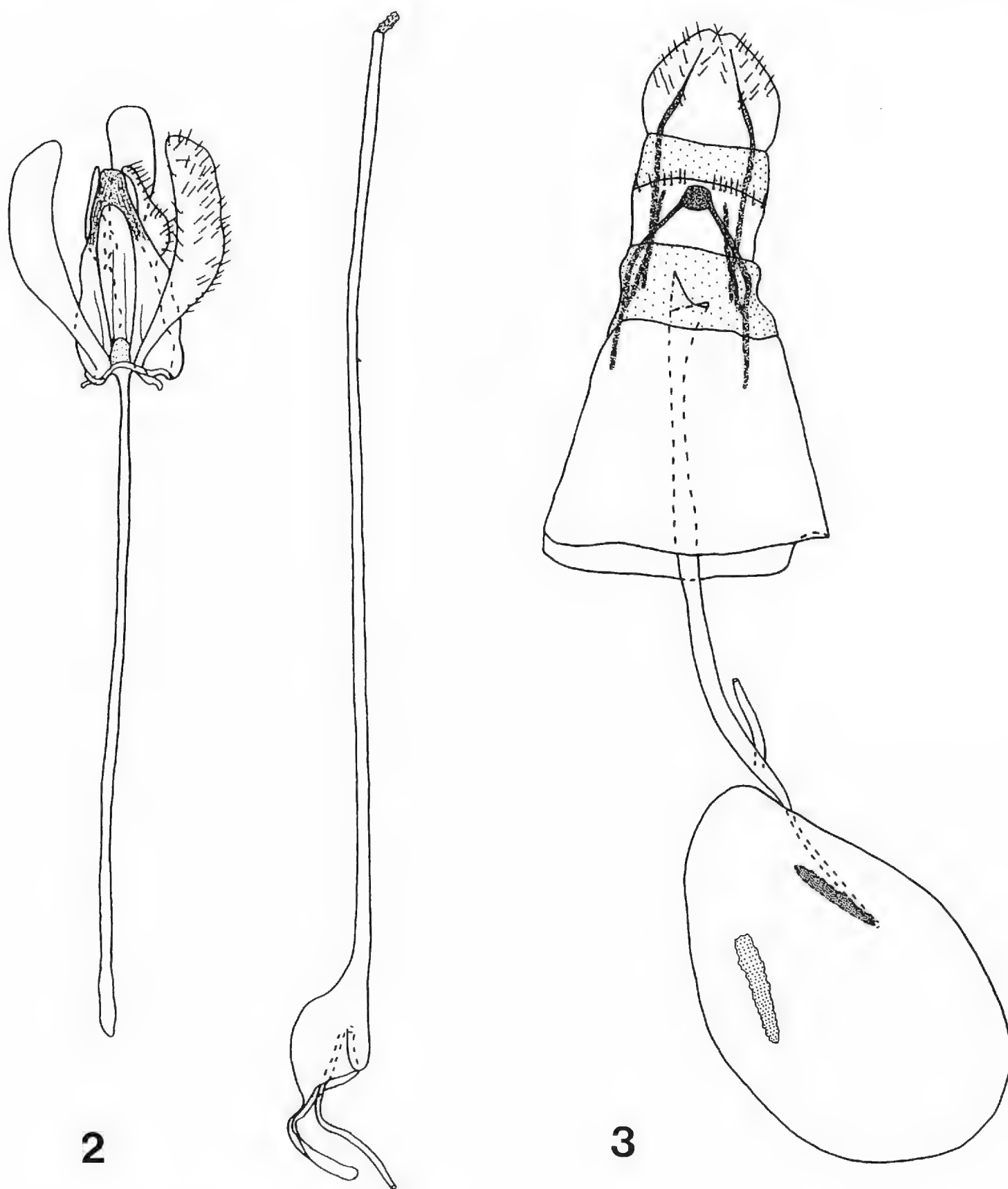


Fig. 2. Male genitalia of *Embola powelli*.

Fig. 3. Female genitalia of *Embola powelli*.

Paratypes (21 males, 20 females).—USA, ARIZONA, *COCHISE Co.*: 1 female, 3 mi NW Chiricahua, 5 August 1991 (Y. F. Hsu & J. A. Powell, UCB). *GRAHAM Co.*: 1 female, Aravaipa Cyn., Wild Turkey Cr., MVL, 26 July 1989 (B. & J. F. Landry, CNC). *PIMA Co.*: 1 male, T19S, R16E, S18, 10 October 1960 (R. W. Hodges, USNM). CALIFORNIA, *IMPERIAL Co.*: 1 male, 2 mi E Mountain Springs, 28 April 1993, reared from *Mirabilis tenuiloba*, emgd. 18 May 1993, JAPN 93D41.1 (Y. F. Hsu, UCB); 1 male, same locality, 18 March 1994, reared from *M. tenuiloba*, emgd. 12 April 1994, JAP 94C62 (Y. F. Hsu & H. H. Chuah, NTNU); 2 males, same locality, 20 July 1994, reared from *M. tenuiloba*, emgd.

25 August 1994, JAP 94G25 (Y. F. Hsu, UCB). *KERN Co.*: 1 male, 4 mi N Red Rock Cyn., 3 May 1968, on *Haplopappus cooperi* (Powell, UCB). *LOS ANGELES Co.*: 2 males, 3 females, San Clemente Is., Seal Cove, Rock Wall Cyn. area, 14 April 1980, associated with *Mirabilis laevis* (= *californica*) (Powell, D. Faulkner, SDNHM, UCB); 1 female, same locality, West Cove, associated with *Mirabilis laevis* (= *californica*), 15 April 1980 (Powell, Faulkner, UCB); 1 female, Whittier, 12 December 1910, on flowers of *Encelia californica* (P. H. Timberlake, USNM). *RIVERSIDE Co.*: 1 male, 4 mi E Elsinore, R. R. Cyn., 17 April 1965 (Powell, UCB). *SAN BERNARDINO Co.*: 1 male, 7 mi SE Kelso, Vulcan Mine Rd., 26 April 1977 (Powell, UCB). *SAN DIEGO Co.*: 4 males, 1 female, 1 mi E Cardiff, 24/31 March 1974 (Powell, SDNHM, UCB); 1 female, La Jolla, 18 June 1963 (Powell, UCB); 1 male, 2 mi NE Lakeside, 400', 30 March 1961, 1 male, same locality, 13 March 1963; 1 male, 1 female, same locality, 24/25 March 1993 (all Powell, UCB); 1 female, 27 April 1993, reared from *M. californica*, emgd. 11 June 1993, JAP 93D39 (Y. F. Hsu, UCB); 1 female, same locality, 16 March 1994, reared from *M. californica*, emgd. 17 April 1994, JAP 94C54 (Y. F. Hsu, H. H. Chuah, UCB). *SANTA BARBARA Co.*: 1 female, Santa Cruz Island, Lower Central Valley, 24 May 1984 (J. F. Landry, CNC). *VENTURA Co.*: 1 male, 1 female, Santa Susana Mtns., Tapo Cyn., 16/19 April 1939, on *M. californica* (L. M. Martin, LACM).

MEXICO, BAJA CALIFORNIA NORTE: 1 female, 4 mi SW La Zapopita, Valle de Trinidad, 16 April 1961 (F. S. Truxal, LACM). *BAJA CALIFORNIA SUR*: 1 female, 30 km E La Ribera, Rancho Las Barracas, 21/24 March 1982 (M. Irwin, E. Schlinger, UCB). *CHIHUAHUA*: 1 female, 12 mi W Hidalgo Del Parral, 6200', 14 July 1964 (Powell, UCB); *DURANGO*: 1 male, 26 mi S La Zarca, 16 July 1964, on *Encelia* (J. A. Chemsak, UCB).

Description.—*MALE*. FW length 2.8–5.4 mm ($3.58 \text{ mm} \pm 0.49 \text{ mm}$, $n = 21$). Head: Frons, vertex metallic gray tinged with blue. Scaling behind eyes cream-white. Antenna metallic dark gray. Labial palpus metallic gray with basal segment cream-white. Thorax: Metallic dark gray tinged with blue. Legs metallic gray tinged with blue. Profemur and mesotibia with distal ends cream-white. Metatibia with a whorl of white scales adjacent to spurs; black scaling in front of the white whorl. Medial spurs of metatibia with inner one $2.2\times$ longer than outer. Forewing: Metallic chrome or flame orange with distal margin metallic gray tinged with blue; 3 costal and 1 dorsal metallic gray spots tinged with blue. A transverse band of same color located at $\frac{1}{3}$ from base; C1 proximal, C2 and C3 distal to transverse band; spots and band edged with black scaling. Extensive black scaling along costa and dorsal margin in some specimens. Fringe gray tinged with orange. Hindwing: Metallic pale gray tinged with blue. Fringe gray tinged with orange, turning cream-white toward tornus. Abdomen: Metallic black banded with silver, with creamy yellow terminal end. Genitalia: As in Fig. 2 (drawn from EME slide 3646, Riverside Co., CA; $n = 8$). Tegumen cone-shaped, attenuate to up-curved, blunt distal end. Socii elongate, dilated at base, rod-like with a blunt, down-curved distal tip, $0.65\times$ tegumen length. Saccus $3.15\times$ tegumen length. Valva broad, elongate with basal portion narrowed. Phallus very narrow, slightly down-curved distally, $1.2\times$ longer than tegumen + saccus. Cornuti a cluster of wart-like protuberances at distal end of aedeagus.

FEMALE. FW length 2.8–4.8 mm ($3.55 \text{ mm} \pm 0.59 \text{ mm}$, $n = 17$). Color pattern as described for male but lacking cream-yellow terminal scaling on abdomen. Genitalia: As in Fig. 3 (drawn from YFH slide 1044, Graham Co., AZ; $n = 7$). Medial, sclerotized, band of apophyses anteriores oval or somewhat rectangular. Ventral signum elongate, irregularly bordered, forming a deeply invaginated band; dorsal signum oval or an elongate, slightly depressed band, length variable, ranging from half long to nearly as long as dorsal signum.

Early Stages.—larva cylindrical, cream colored, with two SV setae on A9 (Hsu & Powell in press); pupa (Fig. 7) cylindrical, brown, with short lateral bristles present on weak lateral ridges on abdomen.

Distribution.—USA. (California, Arizona); Mexico (Baja California Norte, Baja California Sur, Chihuahua, Durango).

Voltinism.—Evidently a multivoltine species, as moths have been collected in all seasons.

Etymology.—This species is named in honor of Dr. Jerry A. Powell who collected the first series of this insect from the type locality, and for his significant contribution to the knowledge of North American microlepidoptera fauna.

Diagnosis.—Within *Embola*, *E. powelli* is unique in having its socii dilated at base and abruptly narrowed toward the distal end. While all the other known *Embola* species have the ventral and dorsal signa different in shape (Hsu & Powell in press), the two signa of *E. powelli* are similar. *E. powelli* is also the only *Embola* with a metallic gray transverse band on the forewing.

Biology.—Larval hosts are *Mirabilis californica* (JAP 93D39, 94C54) and *M. tenuiloba* (JAP93D41.1, 94C62) (Nyctaginaceae) in southern California. The larva is a stem borer that enters the stem by boring a hole at any position on the stem; frass is deposited in the canal made by larva. Pupation occurs in the stem, and the adult emerges from the stem through a hole made in the larval stage. The adult raises its hindlegs in repose.

DISCUSSION

The discovery of biology of *Embola powelli* suggests that the endophagous behavior of the larva may be a general feeding strategy shared by all *Embola* species. Monte (1934) and Costa Lima (1936, 1945) reported larvae of South American *E. obolarcha* (Meyrick) as borers in cecidomyid galls on *Piper* species (Piperaceae). The identity of the moths they observed has yet to be confirmed, but it will confirm the endophagous behavior of *Embola* larvae if their moths were true *E. obolarcha*.

Besides *Embola* species, *Lamprolophus* is the only heliodinid that is known to have larva feeding as a stem borer. In that species, however, the behavior is facultative. Busck (1900) indicated that larvae of *L. lithella* use young stems and eject frass through a hole on the stem (Fig. 4). I further observed larvae of that species leaving a stem to bore into another when the old one deteriorated, and a group of larvae were seen in a single large cavity in a soft, young stem (JAP 94D98). Moreover, the pupal morphology of *L. lithella* is typical of heliodinids, with the body flattened dorsoventrally and with prominent lateral ridges and long, lateral bristles (Fig. 6). In contrast, the larvae of *Embola* are obligate borers, making a linear gallery in the stem and depositing frass within the gallery (Fig. 5). Pupae of *E. powelli* show modifications related to the life style as obligate borers. The body is cylindrical, lateral ridges of the abdomen are greatly reduced, nearly obsolete, and the lateral bristles on abdominal segments are considerably shortened (Fig. 7).

Phylogenetic analysis indicates *Embola* to be more closely related to genera such as *Scelorthus*, *Lithariapteryx*, and *Aetole*, which are either leaf skeletonizer or leafminers during larval stages, than to *Lamprolophus* (Hsu 1995, Hsu & Powell in press). As a result, the stem-boring strategy found in *Lamprolophus* and *Embola* is unrelated and not homologous. Obligate stem boring behavior is found exclusively only in *Embola*, and is hypothesized to be a synapomorphy of members of *Embola* as well as a uniquely derived larval feeding behavior in the

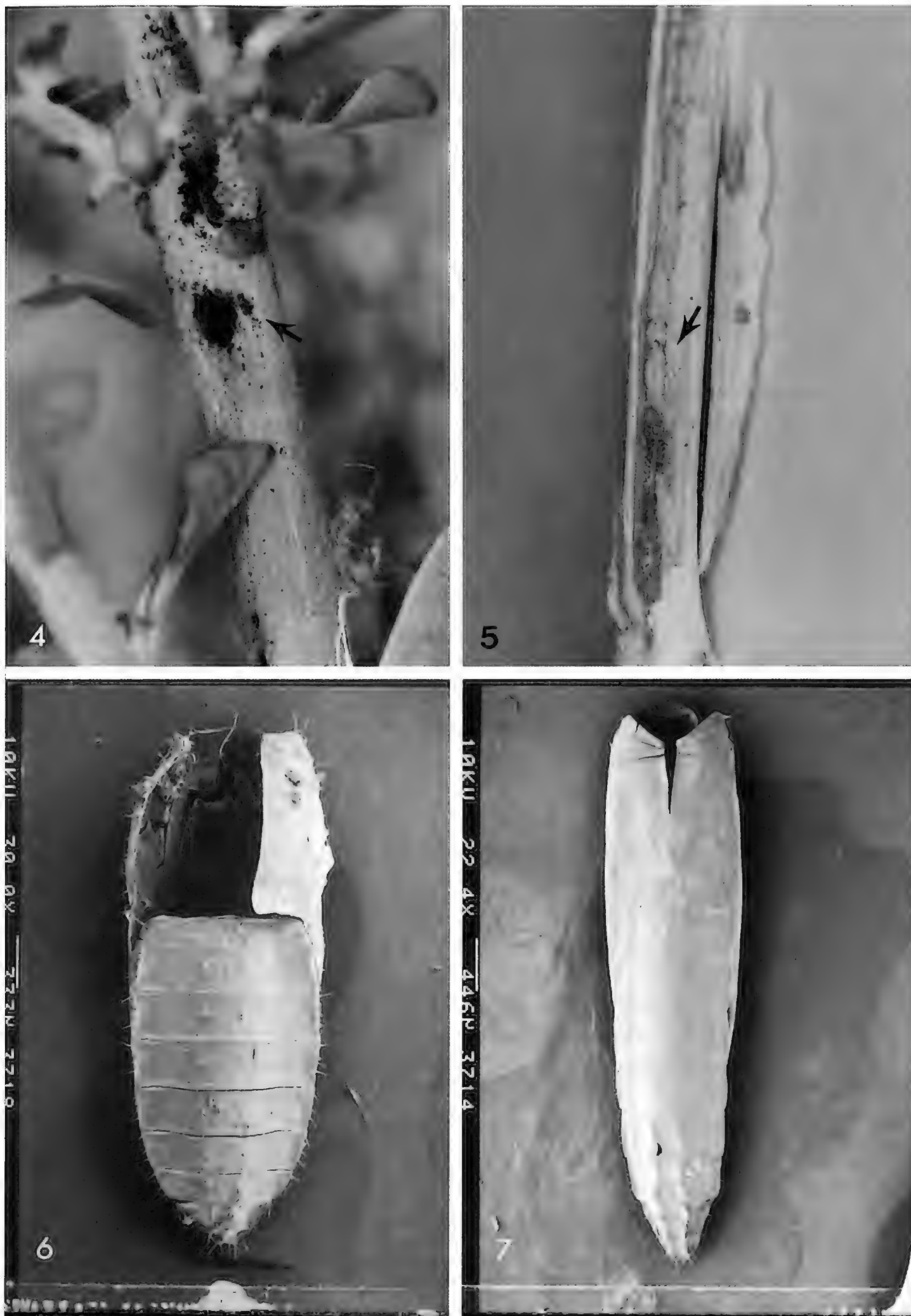


Fig. 4. Feeding hole and extruded frass of *Lamprolophus lithella* on *Pisonia aculeata* (Arrow indicates frass).

Fig. 5. Feeding gallery containing deposited frass by a larva of *Embola powelli* in a stem of *Mirabilis californica* (Arrow indicates frass).

Fig. 6. SEM of pupal shell of *Lamprolophus lithella*.

Fig. 7. SEM of pupal shell of *Embola powelli*.

evolutionary history of Heliodinidae, with morphological modifications associated with the boring feeding strategy present only in the *Embola* lineage.

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SPIDERS (ARANEAE) AS POTENTIAL PREDATORS OF LEAFROLLER LARVAE AND EGG MASSES (LEPIDOPTERA: TORTRICIDAE) IN CENTRAL WASHINGTON APPLE AND PEAR ORCHARDS

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Abstract.—Eleven species of arboreal, hunting spiders, common in central Washington apple and pear orchards, were evaluated as potential predators of the tortricid leafrollers, *Pandemis pyrusana* Kearfott and *Choristoneura rosaceana* (Harris), pests in Pacific Northwest orchards. All species fed on leafroller larvae established on apple and pear seedlings or branches during small cage tests. *Cheiracanthium mildei* L. Koch was the most effective predator in these tests, consuming 65% of larvae. *C. mildei* was also the most effective predator among six species used in tests where leafroller larvae were established on small, caged apple trees. Twelve species of arboreal, hunting spiders were tested as predators of *C. rosaceana* egg masses. *C. mildei* was the most effective egg mass predator and 35 of 112 individuals consumed part or all of an egg mass. In addition, *Oxyopes scalaris* Hentz and *Cheiracanthium inclusum* (Hentz) exhibited some feeding on eggs.

Key words.—Arachnida, Araneae, biological control, *Cheiracanthium mildei*, leafrollers, orchards, predation, spiders.

Spiders are important predators of insects in most terrestrial habitats (Foelix 1996). Apple orchards heavily treated with synthetic, broad-spectrum insecticides have few spiders, but in orchards where these chemicals are not used spider numbers may be much higher (Mansour et al. 1980a, Madsen & Madsen 1982). Even limited use of synthetic, broad-spectrum insecticides in apple orchards results in lower spider numbers compared to orchards where they are not used (Knight et al. 1997, Miliczky et al. 2000).

Spiders have been observed feeding on a variety of apple and pear pest insects (Dondale 1956, Wisniewska and Prokopy 1997, ERM, personal observations) and evidence of their importance in control of some pest species has been presented. MacLellan (1973) showed that spiders were valuable predators of the light brown apple moth, *Epiphyas postvittana* Walker, in Australia and Mansour et al. (1980c) found that spider predation on the Egyptian cotton leafworm, *Spodoptera littoralis* (Boisduval), reduced damage to apple in Israel. The use of synthetic broad-spectrum insecticides in central Washington apple and pear orchards has been decreasing in recent years as new pest control technologies, such as pheromone based mating disruption for codling moth, *Cydia pomonella* L., and specific insecticides, have been adopted (Knight 1995). As a result, spiders and other natural enemies may assume a greater role in orchard pest management programs.

The leafrolling caterpillars, *Pandemis pyrusana* Kearfott and *Choristoneura rosaceana* (Harris) (both Tortricidae), are pests of apple, pear, and other fruit trees in eastern Washington. The bionomics of the two insects are similar as they have two generations per year and overwinter as second and third instar larvae. Both species lay compact masses of up to 300 eggs and, as larvae, roll leaves to form

protected feeding sites (Schuh & Mote 1948, Beers et al. 1993). Larvae feed primarily on foliage but also damage fruit by surface feeding (Beers et al. 1993).

We report here the results of tests designed to evaluate the potential for predation on larvae of *P. pyrusana* and *C. rosaceana* of 11 species of hunting spiders. Twelve species of hunting spiders were also tested as predators of *C. rosaceana* egg masses. Hunting spiders do not construct webs for prey capture but either actively seek prey or wait for prey to come to them (Wise 1993, Foelix 1996). All tested species occur in south-central Washington apple and pear orchards and are frequently found in the tree canopy where there is potential for contact with leafrollers (Miliczky et al. 2000).

MATERIALS AND METHODS

Greenhouse and laboratory tests were conducted at the USDA-ARS Yakima Agricultural Research Laboratory near Wapato, Washington. Tests were also conducted in an outdoor screenhouse and in small, experimental orchards at the USDA-ARS research farm, 26 km east of Yakima, Washington.

Spiders used in the tests were collected in Yakima Co., Washington from apple and pear orchards and adjacent habitat. Spiders not used within two or three days of capture were maintained in the laboratory on live insects including field-collected *Lygus* spp. and laboratory reared Drosophilidae and larval codling moth. Spiders were not starved prior to use in a test. Some individuals were used in more than one test and some were transferred to a second or third cage during a given test.

Small Cage Tests.—Small cage tests were conducted with various plant material, but in all cases infestation with leafroller larvae and introduction of spiders were as follows. Three to five leafroller larvae were placed on leaves of a test plant. Larval size was adjusted according to size of the spiders used in a given experiment because spiders generally take prey smaller than themselves (Wise 1993). Third instars were used in tests with small to medium size spiders; fourth to early fifth instars were used in tests with larger spiders. The plant was then enclosed in one of two types of cage. Cylindrical cages made of flexible, plastic screen (seven mesh per cm) were used in greenhouse, screenhouse, and orchard tests. Cages were 48 cm long and 16 cm in diameter. One end was equipped with a sewn-in, circular piece of screen with an opening for leafroller and spider introduction. The second type of cage, used in laboratory tests with potted seedlings, was constructed of clear, plastic sheeting (Mylar) formed into a cylinder 45 cm tall and 17.5 cm in diameter. The ends of the cylinder were inserted into the tops of paper ice cream cartons. The center of the carton forming the top of the cage was removed and replaced with fine mesh, organdy gauze for ventilation. Leafroller larvae were given one to three days to feed on host plants and establish leafrolls prior to spider introduction. Just before introduction of a spider, a plant was examined to determine the number of established leafroller larvae. Eleven species (five to 50 individuals per species) were evaluated in small cage tests.

Evidence of predation was scored at two to four day intervals after spider introduction. Plants were examined and dead larvae, when found, were inspected under a microscope at 6×–50× to determine cause of death. Larvae killed by spiders showed one or more of the following features: 1) Head capsule and/or pronotum pierced one or more times by the spider's chelicerae, 2) Body markedly

chewed up, shrunken, and discolored, 3) Larva torn into two pieces at some point along its length with one piece often missing, 4) Large wound(s) present with internal fluid/tissue exuding. Test larvae fed on by spiders in the laboratory showed the same features. Dead larvae that did not exhibit one or more of these features were assumed to have died from some other, usually unknown, cause. Often, little remained of a spider-killed larva except the exoskeleton and undigested plant material in the gut. Cast exoskeletons were readily distinguishable from spider-killed larvae. Tests ended when all larvae had been killed, died of other causes, remained unconsumed for several days, or pupated (predation on pupae was originally thought to be unlikely but did occur occasionally—see below). Maximum head capsule width was measured with an ocular micrometer for 109 spider-killed leafroller larvae that were recovered (five *P. pyrusana* and 104 *C. rosaceana*). Head capsule widths of third instar and last instar larvae of *P. pyrusana* and *C. rosaceana* were measured for comparison with head capsules of spider-killed larvae.

Twenty-four small cage tests were conducted using a variety of host plants and plant sizes. Twelve tests were conducted in the laboratory on pear seedlings growing in 9 cm × 9 cm × 9 cm plastic pots and housed in the clear, plastic cages. One test was conducted in the greenhouse using potted apple seedlings (9 cm × 9 cm × 9 cm pots) covered with flexible screen cages. Six tests were conducted on small (2 m tall) apple trees (varieties Red and Golden Delicious) growing in large, plastic pots (55 cm diameter × 45 cm deep) in an outdoor screenhouse. Branches of appropriate length were enclosed in flexible, screen cages. Two tests were conducted in small, apple orchards (varieties Fuji and Golden Delicious) and three were conducted in a small, pear orchard (variety Bartlett). Branches of appropriate length were enclosed in flexible screen cages. Five to 20 cages were used per test depending on availability of spiders or potted plants.

Pandemis pyrusana larvae were used in four laboratory and three field tests on pear and in two screenhouse tests on apple. *Choristoneura rosaceana* larvae were used in eight laboratory tests on pear and in one greenhouse, four screenhouse and two field tests on apple. Both species were from laboratory colonies maintained on artificial diet.

Control cages, seeded with leafroller larvae but without spiders, were maintained in some tests to verify that larvae constructed leafrolls, fed on foliage, and developed normally under the experimental conditions.

Prey presentation in small cage tests was designed to approximate the conditions a spider would encounter in the orchard in that larvae were allowed to establish leafrolls on live plants before spider introduction. However, the small volume of the cage and the high density of leafrollers on the short length of test branch may have made it more likely that a spider would encounter and attack a leafroller than would be the case under field conditions.

Large Cage Tests.—These tests were conducted in an orchard of small Red Delicious apple trees and were designed to more closely approximate actual field conditions than the small cage tests. Trees were lightly pruned, if necessary, to fit inside 1.8 m × 1.8 m × 1.8 m screen cages supported by tubular, metal frames. One wall of a cage was zippered to allow access. Soil was piled around the bottom perimeter of each cage to help prevent escape of spiders and leafrollers. Prior to leafroller introduction, trees were beat with a stiff rubber hose to dislodge poten-

tial predators onto a 0.45 m² tray. Predators were then removed from the cage. Thirty-five *C. rosaceana* larvae (third and fourth instar) were seeded onto each of four trees used in a test. Larvae were placed on young, still-growing leaves. Two to four days later the number of established larvae was counted and spiders were introduced. Trees were inspected at two to four day intervals thereafter to determine the number of surviving leafrollers and to look for evidence of predation: dead larvae and empty leafrolls. These were examined at 6×–50×. Tests were continued until surviving *C. rosaceana* had pupated.

Spiders used in large cage tests were species judged to have the greatest potential as leafroller predators based on small cage test results. Three large cage tests were conducted. The first was run from 6 to 24 July 2000 and used females or large immatures of five species: *Oxyopes scalaris* Hentz (Oxyopidae) and four species of Salticidae, *Eris militaris* (Hentz), *Phidippus audax* (Hentz), *P. clarus* Keyserling, and *P. comatus* Peckham & Peckham. One individual of each species was placed in each of two cages. Two control cages received leafroller larvae only. The second test (31 July–22 August 2000) employed four female *P. clarus* in one cage, four female *P. comatus* in one cage, two female and two large immature *Cheiracanthium mildei* L. Koch (Clubionidae) in one cage, and one cage was a control. Five immature (ca. one-half grown) *C. mildei* were used in each of three cages for the third test (30 August–18 September 2000). The fourth cage was a control.

Egg Mass Predation Tests.—Egg masses of *C. rosaceana* were used in all tests. Egg masses were presented to spiders in three ways. Initially, egg masses laid on wax paper were obtained from the rearing facility at the Yakima laboratory. Egg masses on wax paper were attached to pear leaves with double-sided tape in a pear orchard at the experimental farm. Branches with egg-bearing leaves were enclosed in flexible, screen cages and spiders introduced. Seven to ten individuals of three species were tested: *Pelegrina aeneola* (Curtis) (Salticidae), *Misumenops lepidus* (Thorell) (Thomisidae), and *Philodromus cespitum* (Walckenaer) (Philodromidae).

Caged female moths were allowed to lay eggs on potted apple or pear seedlings for a second series of tests. Egg-bearing leaves were clipped and the petiole inserted through a hole in the cap of a water-filled, 145 ml plastic vial. The leaf blade was enclosed in a second vial attached above the water vial. The spider was housed in the upper vial, the end of which was screened for ventilation. Tests were continued until the eggs were consumed, reached the black-head stage, or hatched. Five to 100 individuals of the following species were tested: *P. aeneola*, *P. comatus*, *P. clarus*, *P. audax*, *E. militaris*, *O. scalaris*, *C. mildei*, *Cheiracanthium inclusum* (Hentz), *Xysticus cunctator* Thorell (Thomisidae), and *Anyphaena pacifica* (Banks) (Anyphaenidae).

A final series of tests utilized 30 cm tall, potted pear seedlings whose leaves bore one or more egg masses. Seedlings were enclosed in cylindrical plastic cages (described above) and a spider was introduced. Tests were continued as before. Twelve *C. mildei* were tested.

RESULTS

Small Cage Tests.—Both leafroller species constructed normal leafrolls on apple and pear. Percent of larvae in control cages that survived to the end of the experiments was, however, about twice as high on apple as it was on pear (Table 1).

Seven of 11 spider species were tested on both apple and pear. Because predation rates by these species were similar on both plants, results for all small cage tests are combined in Table 1. Predation rates on leafroller larvae among the 11 species ranged from 5% to 65% based on spider-killed larvae that were recovered and examined microscopically (Table 1). Table 1 also indicates that some larvae were unaccounted for at the ends of experiments based on the number of larvae that established leafrolls prior to spider introduction. Some of these larvae probably abandoned their leafrolls and escaped from the cages or were otherwise unaccounted for. Some larvae, however, may have been killed by spiders but their remains were not recovered. If this was the case then predation rates may have been somewhat higher than those given in Table 1.

Cheiracanthium mildei was the most effective predator of leafroller larvae. Predation rates by this species were the same on apple and pear (65%). Only two of 37 individuals failed to consume at least one larva and both escaped and were lost during testing. On the other hand, one adult female consumed 14 of 20 leafrollers during the course of three separate tests. She ate larvae, including last instars, a pupa, and an emerged adult. A second adult female consumed all five larvae in one cage within three days and four of five larvae in a second cage within four days. Adult female *C. mildei* seemed especially voracious predators. *Cheiracanthium inclusum* was less effective, consuming 35% of larvae.

Among the other species, the four largest salticids (*E. militaris* and the three species of *Phidippus*) and the lynx spider, *O. scalaris*, consumed 28–51% of larvae. The remaining four species each consumed fewer than 20% of the larvae.

Large Cage Tests.—Results of the large cage tests are summarized in Table 2. Leafroller establishment in the first test was high in all four cages, but predation by the spiders was low; one larva killed in one cage and two in the second. Low levels of parasitism by *Colpoclypeus florus* (Walker) (Hymenoptera: Eulophidae) occurred in all cages.

Only four of 28 larvae were killed by *P. comatus* during the second large cage test and no predation by *P. clarus* was observed. Both species had performed much better in small cage tests. *C. mildei*, however, destroyed 10 of 27 larvae, 16 others were unaccounted for, and only one survived to the end of the test.

Predation by *C. mildei* during the third, large cage test ranged from 12% to 29% and several larvae were unaccounted for in each cage. All larvae not killed by the spiders or unaccounted for were parasitized by *C. florus* and no leafrollers survived to the end of the test, including those in the control cage.

Sizes of leafroller larvae preyed upon by four spider species and by different sizes of individuals within a species overlapped considerably (Table 3). Mean head capsule width of third instar *P. pyrusana* larvae was 0.55 mm (range: 0.47–0.58 mm; $n = 23$) and mean width of last instars was 1.66 mm (range: 1.41–1.84 mm; $n = 19$). Corresponding dimensions for *C. rosaceana* were slightly larger: 0.59 mm (range: 0.57–0.61 mm; $n = 4$) for third instar and 1.77 mm (range: 1.46–2.00 mm; $n = 6$) for last instar larvae. All species and size classes of spiders, except male *P. comatus*, preyed on leafroller larvae that were within the size ranges of last instar *P. pyrusana* and *C. rosaceana*. Earlier instars were also preyed upon (Table 3). These four spider species were among the largest tested and most individuals were adults or large immatures ($> \frac{1}{2}$ grown) when used in the experiments.

Table 1. Small cage test results. Spiders tested for feeding propensity on two species of leafroller larvae (LR) in laboratory, greenhouse, field cage, and field situations on apple and pear foliage.

Spider species	Spider family	No. individuals tested	No. LRs available	% LRs eaten	% LRs not accounted for	% LRs survived
<i>Cheiracanthium mildei</i> ^a	Clubionidae	37	204	65	25	10
<i>Eris militaris</i> ^a	Salticidae	15	69	51	23	26
<i>Phidippus comatus</i> ^a	Salticidae	50	193	41	35	24
<i>Oxyopes scalaris</i> ^a	Oxyopidae	11	47	40	13	47
<i>Phidippus clarus</i> ^a	Salticidae	45	157	36	28	36
<i>Cheiracanthium inclusum</i> ^a	Clubionidae	14	62	35	23	42
<i>Phidippus audax</i> ^a	Salticidae	5	18	28	56	17
<i>Philodromus californicus</i> ^b	Philodromidae	7	33	18	45	36
<i>Phanias</i> sp. ^b	Salticidae	7	31	13	42	45
<i>Pelegrina aeneola</i> ^c	Salticidae	19	43	7	44	49
<i>Anyphaena pacifica</i> ^b	Anyphaenidae	9	38	5	50	45
Control (apple)	—	—	51	—	18	82
Control (pear)	—	—	20	—	55	45

^a Species tested on both apple and pear.
^b Species tested on pear only.
^c Species tested on apple only.

Table 2. Large cage test results. Fates of leafroller larvae on small, caged apple trees when exposed to different species of spiders. See text for details.

Contents of cage	No. LRs established	% LRs eaten	% LRs not accounted for	% LRs parasitized	% Other mortality	% LRs survived
Large Cage Test #1						
Spider 1	31	3	26	3	3	65
Spider 2	31	6	0	6	6	81
Control 1	31	—	10	13	10	68
Control 2	28	—	11	4	0	86
Large Cage Test #2						
<i>P. comatus</i>	28	14	18	0	7	61
<i>P. clarus</i>	26	0	0	0	0	100
<i>C. mildei</i>	27	37	59	0	0	4
Control	22	—	50	0	0	50
Large Cage Test #3						
<i>C. mildei</i> 1	31	26	26	48	0	0
<i>C. mildei</i> 2	25	12	28	60	0	0
<i>C. mildei</i> 3	31	29	16	55	0	0
Control	18	—	17	83	0	0

Table 3. Head capsule widths of leafroller larvae consumed by four spider species and different size classes within spider species during predation experiments.

Spider species	Spider stage (No. tested)	Mean spider carapace width ¹	Mean LR head width	Range in LR head widths	No. LRs measured
<i>C. mildei</i>	female (4)	2.56 mm (10)	1.41 mm	1.1–1.7 mm	7
<i>C. mildei</i>	sub-female ² (2)	—	1.44 mm	1.0–1.8 mm	5
<i>C. mildei</i>	immatures ³ (8)	—	1.20 mm	0.8–1.7 mm	28
<i>C. inclusum</i>	immatures (4)	— ⁴	1.14 mm	0.8–1.7 mm	6
<i>P. clarus</i>	female (1)	3.49 mm (10)	1.40 mm	0.7–1.7 mm	5
<i>P. clarus</i>	sub-female (2)	—	1.65 mm	1.5–1.8 mm	4
<i>P. clarus</i>	immatures (10)	—	1.29 mm	1.0–1.8 mm	22
<i>P. comatus</i>	sub-female (6)	2.60 mm (2) ⁵	1.52 mm	1.0–1.9 mm	10
<i>P. comatus</i>	male (3)	2.94 mm (10)	1.10 mm	1.0–1.2 mm	7
<i>P. comatus</i>	sub-male (7)	1.95 mm (1)	1.33 mm	0.9–1.6 mm	13
<i>P. comatus</i>	sub-sub-male (2)	—	1.55 mm	1.4–1.7 mm	2

¹ Number of specimens measured is given in parentheses.
² Sub-female and sub-male spiders are one molt from reaching adulthood. Sub-male status determined by enlarged but undifferentiated, terminal segment of the pedipalp. Sub-female status determined by subsequent rearing.
³ Immature spiders of all species were approximately one-half grown or larger but do not include sub-adults.
⁴ Mean carapace width of adult female *C. inclusum* = 2.28 mm (*n* = 4). Immatures used here were approximately one-half grown.
⁵ Probable sub-females. Mean width of adult female = 3.23 mm (*n* = 10).

Egg Mass Predation.—No predation was observed on egg masses laid on wax paper and taped to leaves of pear trees by the three species tested in this way. Also, seven of ten species did not feed when housed in small, plastic vials with single apple or pear leaves on which an egg mass had been laid. However, two of 25 *O. scalaris* and one of seven *C. inclusum* consumed part or all of an egg mass during single leaf tests. *C. mildei* was the most effective egg predator in single leaf tests and 29 of 100 individuals fed on egg masses, often consuming them in their entirety within 24 hours. Eighteen of the 100 *C. mildei* were tested twice. Eleven failed to feed either time, six fed once, and one fed on eggs in both tests. Unconsumed eggs in a fed-upon mass often developed normally. Six of 12 *C. mildei* also fed on eggs laid on leaves of 30 cm tall pear seedlings. Two of these spiders consumed three masses each and a third individual consumed two masses and part of a third.

DISCUSSION

Several spider species that occur in central Washington orchards preyed on leafroller larvae during these tests. *C. mildei* was the most effective predator in both small and large cage tests. This species is a native of the Mediterranean region and was probably introduced into North America (Edwards 1958). It is widely distributed in central Washington orchards (Miliczky et al. 2000, E.R.M. personal observation). *C. mildei* is a long-legged, swift running, nocturnal hunter that reaches an adult body length of 10 mm (Dondale & Redner 1982). Spiders were often found in silken retreats on leaves during daytime cage inspections. Other studies have indicated the importance and versatility of *C. mildei* as a predator of pest insects. It was the dominant spider in an unsprayed apple orchard

in Israel where it was an effective predator of the Egyptian cotton leafworm, *Spodoptera littoralis* (Boisduval), (Mansour et al. 1980a). Specialized predation on cryptic larvae of the leafminer, *Phyllonorycter blancardella* (F.), was reported by Corrigan & Bennett (1987). They observed small holes in the lower surface of leaf mines, from which larvae were absent, and attributed the holes and absence of larvae to predation by *C. mildei*. Our unpublished observations showed that *C. mildei* employed specialized behaviors when attacking leafroller larvae including the cutting of small holes in rolled leaves. Wise (1993) speculated that *C. mildei*, because of its abundance and effective hunting techniques, may make important contributions to pest suppression in a number of agroecosystems.

C. inclusum, a species native to North America (Edwards 1958), was found less frequently in central Washington orchards than *C. mildei* (Miliczky et al. 2000, ERM personal observation). The two species are similar in size and appearance. *C. inclusum* is a common spider in western Oregon apple orchards (Bajwa & AliNiazee 2001) and is also abundant in central California vineyards (Costello & Daane 1999). Peck & Whitcomb (1970) described *C. inclusum* as “an indiscriminate and voracious feeder” that accepted a wide range of insect prey in laboratory trials including larvae of several species of Lepidoptera. It may be of importance as a predator of citrus leafminer, *Phyllocnistis citrella* Stainton, in Florida citrus groves (Amalin et al. 2001). *C. inclusum*’s predation rate in small cage tests (35%) was about half that recorded for *C. mildei*.

Several spider species showed high predation rates on leafroller larvae in small cage tests but consumed few, if any, larvae in large cage tests. These spiders, the salticids, *P. comatus*, *P. clarus*, *P. audax*, and *E. militaris*, and the oxyopid, *O. scalaris*, are all diurnal hunters with good eyesight and visually oriented hunting strategies (Wise 1993). *Phidippus* spp. are heavy-bodied, hairy, often colorful spiders whose adult body lengths frequently exceed 10 mm (Kaston 1978). *E. militaris* and *O. scalaris* are smaller. Observations of predatory behavior in these species showed little tendency to invade leafrolls and extract larvae. Rather, they appeared opportunistic in their predatory behavior and were quick to snatch exposed larvae. In small cages where prey densities were high, these spiders may have had frequent opportunities for predation on exposed or partially exposed larvae. Similar opportunities may have been infrequent in the large cages where leafroller densities were lower and the trees presented a much greater area to be searched for prey.

Spider predation on insect eggs appears to be quite common; members of the Clubionidae, Oxyopidae, Salticidae, Lycosidae, and Anyphaenidae are the most frequently reported egg predators; and eggs of Lepidoptera are most commonly preyed upon (Nyffeler et al. 1990). Predation on an egg mass of the eastern spruce budworm, *Choristoneura fumiferana* (Clemens), by the jumping spider, *Pelegrina flavipes* (G. & E. Peckham), was reported by Jennings & Houseweart (1978). *C. mildei* was quite an effective predator of leafroller egg masses in these tests where search area was limited to a single leaf or a small seedling. Some individuals, however, failed to feed on eggs even after four or five days in close proximity to them. Mansour et al. (1980b) noted that *C. mildei* spiderlings fed on infertile, conspecific eggs within the egg sac, a behavior also noted for *C. inclusum* (Peck & Whitcomb 1970). One of seven *C. inclusum* fed on a leafroller egg mass in our tests, and the species has also been found to prey on eggs of the tobacco

budworm, *Heliothis virescens* (Fabricius), (McDaniel & Sterling 1982) and the velvetbean caterpillar, *Anticarsia gemmatilis* Hubner (Buschman et al. 1977).

The tests described above show that among several species of hunting spiders found in central Washington orchards a range of abilities as predators of leafroller larvae exists. Some species showed little potential whereas *C. mildei* was quite effective, a conclusion supported by the consistent performance of numerous individuals during small cage tests and *C. mildei*'s markedly better performance in the large cage tests compared to other species. *C. mildei* may also be quite an effective egg mass predator. Although leaf area searched during egg predation tests was tiny compared to that of an entire tree, the belief that egg mass predation by *C. mildei* may occur in the field is strengthened by the fact that 35 of 112 individuals consumed eggs whereas only three individuals among the other 11 species (149 total individuals) did so. In orchards where *C. mildei* and some of the other species are present, spiders may contribute substantially to natural control of leafroller pests.

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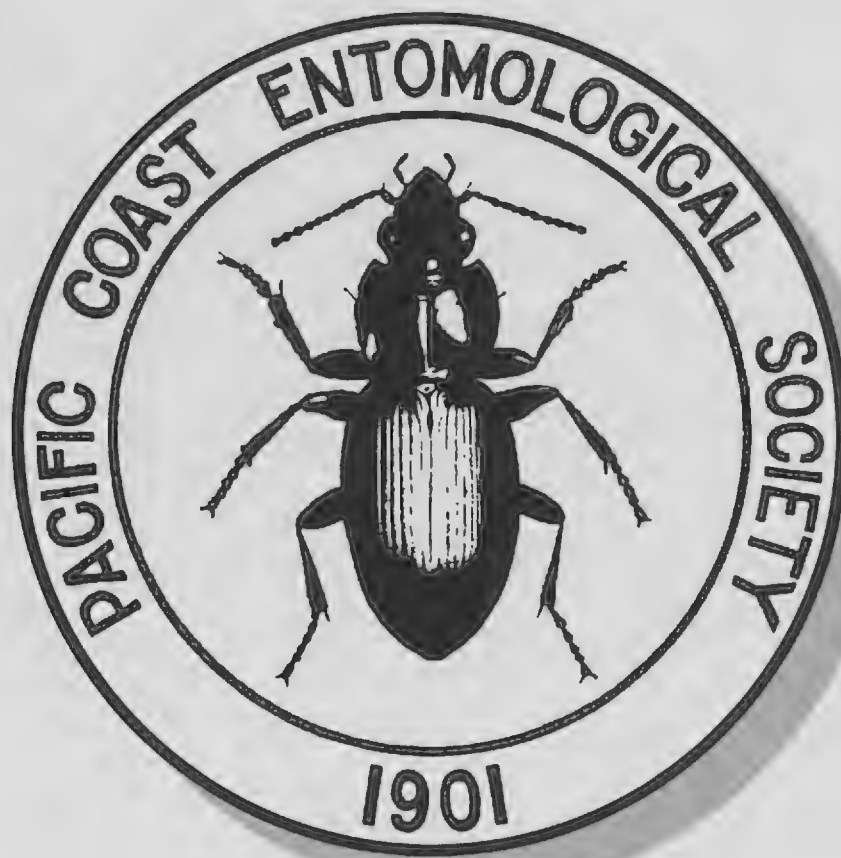
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**OBITUARY AND BIBLIOGRAPHY OF KENNETH S.
HAGEN (1919–1997), DEDICATED ENTOMOLOGIST
AND TEACHER**

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Kenneth Sverre Hagen, professor emeritus of Entomology at the University of California, Berkeley, and past president of the Pacific Coast Entomological So-



Figure 1. Collecting trip in Sunset Valley, near Santa Barbara, California in 1939, with (L–R) Edwin Van Dyke, Burdett White, Bill Barr & Ken Hagen.

ciety, died suddenly of a ruptured aortic aneurism on 10 Jan 1997. He is survived by his wife Maxine, his son Kent, and his brother Paul. Worldwide he was regarded as an authority on biological control and insect nutrition. Those who worked with him, also regarded him as the first one to go to for an identification, a literature source, or a cup of coffee.

Ken was born in Oakland, California on 26 Nov 1919. His parents were from Norway, and his father was a seaman, serving on such ships as the *Balclutha*, and eventually reached the rank of first mate. Ken's mother passed away when he was a teenager, and he and his brother had to fend for themselves when their father was away on a voyage.

As a boy, Ken enjoyed chemistry and natural history, and collecting insects was a favorite pastime, but it was a favored teacher in the 9th grade at Lockwood Junior High School who recognized his talents and stimulated him to focus on science as a career. Ken attended Fremont High School in Oakland, where he played football and set a high jump record in track. He graduated from Fremont High in 1938, and then enrolled in San Francisco State College. During this time, his love of natural history led him to the California Academy of Sciences, first as a part-time preparator of insects, and later as an assistant caretaker in the Steinhart Aquarium. He went collecting with Edwin van Dyke, and climbed Mt. Whitney with his fellow coleopterist, Bill Barr. At San Francisco State he continued to play football, and received his A.A. degree in 1942.

Ken then attended U.C. Berkeley, where he was offered a football scholarship. However, Ken did not play football at Cal, but concentrated on his studies (taking up to 24 units a term) to earn his B.S. in entomology in 1943. He then went to

Officer Candidate School at Columbia University, where was commissioned in the U.S. Navy as one of the "90 day wonders". Ken was then given a brief leave, which he used to return to Oakland and marry his fiancée, Maxine White, on 1 Dec 1943. A week later he went to Norfolk, Virginia to attend Amphibious Training School, and then was shipped out to Europe.

During the war he served on the USS Anne Arundel, as a lieutenant in charge of a landing craft section, and saw action in the Neptune Invasion at Omaha Beach in Normandy, and the Dragon Invasion in the south of France in 1944. In 1945, he participated in the landings at Okinawa (where the fierce fighting stranded his boat on the beach overnight), and later helped transport Chinese troops. He developed quite a reputation among his comrades for his entomological interests—en route for the Pacific, Ken was seen leaning over the rail with a net, sweeping the vegetation while passing through the Panama Canal.

In 1946, Ken came back to California and was hired as the supervising entomologist for the West Side Alfalfa Pest Control Association in California's Central Valley, responsible for overseeing 10,000 acres of alfalfa, and becoming the first supervised control entomologist in California. This position played a key role in the development of integrated pest management, and was the predecessor of today's pest control advisor. Ken then returned to Berkeley as a graduate student, working as a technician in the Division of Biological Control. He received his M.S. there in 1948, and his Ph.D. in 1952, under the direction of Richard Doutt. This was a particularly rich time to be at Berkeley, as Ken studied under such luminaries as E. O. Essig, E. G. Linsley, R. L. Usinger and A. E. Michelbacher. He also spent a year in Oahu working on the oriental fruit fly with Robert van den Bosch, and worked in the statewide Department of Biological Control under Harry Scott Smith, whose signed photograph was one of Ken's treasured possessions. He was appointed Junior Entomologist in the Division of Biological Control, Agricultural Experiment Station (at the Gill Tract in Albany, California) in 1952, and advanced to Entomologist in 1965, and to Professor of Entomology in 1969. Ken took a special leave of absence from 1961 to 1963 to work for the government of Greece to advise and develop culturing techniques for the olive fly. He officially retired in 1990, but continued to work at the Gill Tract until the day of his death. It was remarked that the way you knew Ken was retired was that he only worked half a day on Saturday.

Biological control was his passion as well as his profession. Biocontrol has been subdivided into the three tactics of importation, conservation and augmentation. Evidence of Ken's solid training and great command of the field was that he was well-versed in all three. Besides publishing on the history of biological control, Ken was involved in the importation of the natural enemies of pear psylla, acacia psyllid, spotted alfalfa aphid, blue alfalfa aphid, pea aphid, walnut aphid, plum aphid, european asparagus aphid, iceplant scales, Egyptian alfalfa weevil and walnut husk fly. He was familiar with the conservation of the natural enemies through his work on population monitoring and reducing insecticide usage for *Colias* caterpillars and aphids in alfalfa.

However, it was in the area of augmentation of natural enemies, coupled with insect nutrition, that Ken made his most important contributions to science. He was the first to develop an "artificial egg" for the mass-rearing of *Chrysoperla*, and helped develop artificial diets for mass-rearing *Trichogramma*, coccinellids



Figure 2. Some pioneers of modern biological control in Palm Canyon, Riverside County, California in 1948 (L–R) (front row) Stan Flanders, Glen Finney, Charles Fleschner, P. H. Timberlake, Everett Dietrick & Paul DeBach; (second row) Blair Bartlett, Ken Hagen, Prof. Harry Smith, Dave Lloyd, Harold Compere & Ed Steinhaus; (third row) Carl Huffaker, Ken Hughes (kneeling), Ted Fisher & A. J. Baisinger.

and tephritids. His innovative work, with Richard Tassan, on food sprays for predators was a major breakthrough in biological control and continues to serve as a basic example for augmentation of field populations of entomophagous insects. Ken considered that his most significant research contribution was presented in a 1986 paper, wherein he hypothesized that the occurrence of amino acids in honeydew helped protect honeydew producers from ant predation, and presented data showing that chrysopids were attracted to a combination of plant volatiles and kairomones from honeydew, but the attraction varied with the age of the crop.

Ken was truly a scientist of international stature and experience. He engaged in collaborative research in Mexico, Central America, Brazil, Greece, Kenya and China, but his travels also extended through Europe to India, Malaysia, Australia, New Zealand and Chile. Of the 22 visiting scientists and postdoctoral students he hosted in his lab, 18 were from other countries, and of the 28 graduate students he supervised, eight were from other countries, while he was an external examiner of dissertations of another ten students from outside the United States.

Ken's research interests extended beyond biological control, including aquatic Hymenoptera and the immature stages of Hymenoptera, but especially the biosystematics of Hymenoptera (Encyrtidae) and Coleoptera (Coccinellidae and Anthicidae). His work with the Coccinellidae included documenting the complex migratory behavior of the convergent ladybeetle, which involved the use of hot air balloons and scoops fitted onto fixed wing aircraft to sample airborne beetles. This work led to an article in the *National Geographic* (1970) entitled "Following



Figure 3. At Gill Tract, Albany, California in 1985: (L–R) Chuck Kennett, Carl Huffaker, Dick Douthett & Ken Hagen.

the ladybug home”. Ken was particularly pleased with that issue, since it also included an article on his ancestors, the Vikings.

He codescribed *Karpinskiella paratomicobia* (Hymenoptera: Pteromalidae) (Hagen & Caltagirone 1968), and had the following patronyms named in his honor: *Notoxus hageni* (Coleoptera: Anthicidae) (Chandler 1982), *Gnathowisea hageni* (Coleoptera: Coccinellidae) (Gordon 1985), *Olla hageni* (Coleoptera: Coccinellidae) (Vandenberg 1992), *Meleoma kennethi* (Neuroptera: Chrysopidae) (Tauber 1969), *Metaphycus hageni* (Hymenoptera: Encyrtidae) (Daane & Caltagirone, 1999), and the Hagen glands in Braconidae (Hymenoptera) (Buckingham & Sharkey 1988).

Ken was a member of the Entomological Society of America (president of the Pacific Branch in 1979 and fellow), American Entomological Society, Entomological Society of Canada (fellow), Pacific Coast Entomological Society (president 1968–69 and Honored Member), Entomological Society of Washington, Kansas Entomological Society, Hawaiian Entomological Society, Georgia Entomological Society, Society of Systematic Zoology, the Coleopterists Society, American Association for the Advancement of Science (fellow), American Institute of Biological Sciences, International Society of Hymenopterists, and the International Organization of Biological Control (president 1980–84).

He was honored at the 1989 national meeting of the Entomological Society of America with a symposium entitled “Native and Introduced Predaceous Coccinellidae: A Tribute to Kenneth S. Hagen for His Contributions to Coccinellid Biology”. In 1990 he was the recipient of the prestigious Berkeley Citation presented by the University of California, Berkeley, for outstanding service to the

University, and honored by the California State Senate Rules Committee Resolution #2513. In 1992 he received the Distinguished Service Award by the Association of Applied Insect Ecologists and the Lifetime Excellence in Entomology from the Hawaiian Entomological Society, and in 1993, the Distinguished Service Award (Honored Member) by the Pacific Coast Entomological Society. In 1995 the International Organization of Biological Control presented Ken with the Distinguished Biological Control Science Award, and he presented an invitational talk on the Chemical Ecology of Chrysopidae at the IOBC's conference honoring him. In 1998, a review of forage alfalfa pest management was dedicated to Ken (Summers 1998).

Irrespective of these many scientific honors, Ken Hagen was probably best known among his colleagues for several personal traits. First, he always kept a pot of coffee going in his lab, and this served as a focal point for staff and visitors to drop in and discuss entomology. Second, he had a virtual encyclopedic knowledge of entomology and biological control. At the Gill Tract, it was generally understood that if you had a question, your first stop should be Hagen's office. And if he didn't immediately know the answer to the question, as often as not, he was able to swivel around in his chair, and from his immense reprint collection pick out the appropriate reference. Finally, he was extremely generous with his time and knowledge. No matter who approached him, be it a professor, graduate student, staff personnel, farmer or member of the general public, Ken would be happy to lay aside whatever he was working on, and give that person his full attention until he got the answer, or could refer the person to the correct authority. And if the search dragged on, it did no good to tell Ken to forget it—he just “hung in there” and kept looking for your answer. Ken was also popular with the local elementary school teachers, taking out the young students to the Gill Tract's alfalfa field and showing them how to sweep for insects. To Ken, this commitment to teach others about entomology was as natural as can be, possibly reflecting his own debt of gratitude to those teachers who helped him, and he willed his substantial entomological library to the Division of Biological Control.

Ken liked working with wood and was a fine carpenter. He was also interested in sailing, stamp collecting, astronomy, and (due to his studies of anthicids) sand dunes. However, outside of entomology, Ken's greatest interest was book collecting. He was a keen bibliophile, and would bind his own books. His book and journal collection eventually outgrew his house, and when the house next to his came up for sale, Ken and Maxine ended up buying it, largely to use the garage as a storage space for his overflowing library.

A tireless researcher, a loyal and dedicated member of the University of California faculty, an enthusiastic teacher, a helpful and stimulating colleague, and a generous human being, Ken Hagen was, in every sense of the word, a true gentleman.

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NICKEL ACCUMULATION IN SERPENTINE ARTHROPODS FROM THE RED HILLS, CALIFORNIA

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Abstract.—Serpentine soils are characterized by high levels of heavy metals (e.g., Ni, Fe, Cr), and low levels of important plant nutrients (e.g., P, Ca, N). Due to these inhospitable edaphic conditions, serpentine soils are typically home to a very specialized flora. Although much is known about the serpentine flora, almost no research has investigated the arthropods of serpentine areas. In this study, we sampled the arthropods associated with *Streptanthus polygaloides* (Gray), a Ni hyperaccumulator, and the arthropod community of the surrounding serpentine area in the Red Hills of California. Arthropods were then analyzed for Ni content to investigate Ni transport within the serpentine ecosystem. Arthropods associated with *S. polygaloides* contained significantly higher concentration of Ni than those collected in the surrounding community. One insect associated with *S. polygaloides*, *Melanotrichus boydi* Schwartz and Wall (Hemiptera: Miridae), accumulated 770 μg Ni/g.

Key Words.—Insecta hyperaccumulation, serpentine arthropods.

Whereas some heavy metals are essential nutrients and are crucial to the survival of most organisms, in excessive doses they also can be toxic. At many sites heavy metal concentrations in the environment are artificially elevated due to anthropogenic influences such as mining and metal smelting. Because it is possible in some cases to know when human-caused metal contamination began (Brooks 1998), many authors have been able to conduct research on rates of adaptation of organisms to metal contamination (e.g., Wu et al. 1975, Posthuma 1990). This research is not only interesting from a microevolutionary standpoint but also has revealed physiological and genetic mechanisms by which organisms adapt to high concentrations of metal in the environment. However, the relatively recent history of anthropogenic metal contamination at mines and smelters precludes studying the effects of heavy metals on these human-impacted ecosystems over longer time spans.

Serpentine soils provide an opportunity to study long-term effects of heavy metals on ecosystems. Distributed around the globe, serpentine soils are high in heavy metals such as Ni, Fe, and Cr but are low in important plant nutrients like Ca and P (Brooks 1987). Within North America, there are extensive areas of serpentine soils in California and Oregon (Kruckeberg 1984). Whereas Coleman (1967) suggested that these serpentinized areas of California and Oregon have been exposed since the Tertiary, a more recent hypothesis by Raven and Axelrod (1978) suggests a much younger origin for these sites (3 to 24 million years ago). In either case, plant and animal species in these areas have had millions of years in which to adapt to the unique edaphic conditions provided by serpentine soil.

The serpentine flora of California has been the subject of botanical research since the late 1800's (Kruckeberg 1984). Much of this research has focused on

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the adaptations of plants to the unique edaphic conditions of serpentine soils (Brooks 1987). Of particular interest has been the accumulation of Ni by plants. Serpentine plant species commonly accumulate higher levels of Ni than nonserpentine species (Brooks 1987). Moreover, some species of serpentine plants, termed "hyperaccumulators," contain over 1000 μg Ni/g (Brooks et al. 1977). These concentrations of Ni have been found to defend plants against many types of herbivores (see reviews by Boyd and Martens 1998, Boyd 1998). The high Ni concentration in Ni hyperaccumulators provides a unique environment to which herbivores must adapt in order to utilize these plants as a food source.

Many authors have hypothesized that there should be a unique fauna associated with the serpentine flora (Proctor and Woodell 1975, Kruckeberg 1984, Brooks 1987), but little research has specifically addressed this idea. The purpose of this study was to assess interspecific differences in the Ni concentration of arthropods associated with a serpentine community with an emphasis on insects associated with metal hyperaccumulating plants.

MATERIALS AND METHODS

Study Site.—This study was conducted in the Red Hills Management Area in Tuolumne County, California. The entire management area is underlain with serpentine soils (Franklin et al. 1997). Much of the community-level sampling in this study took place in a large (ca. 2000 m^2) area along Red Hills Road in the Red Hills Management Area. The vegetation was dominated by *Ceanothus cuneatus* (Hook.) Nutt., *Clarkia biloba* (Durand) Nels & Macbr., *Calycadenia multiglandulosa* ssp. *bicolor* (Greene) Keck, and *Streptanthus polygaloides* Grey. Species-specific sampling took place throughout the Red Hills Management Area, but was concentrated at the location described above.

Community-level Sampling.—We sampled arthropods within the general serpentine community of the Red Hills Management Area via both pitfall-trapping and black-lighting. In June 1996 and 1997, 21 pitfall traps were placed at the study site. Traps were arranged in an approximately 30 m by 70 m grid. Traps were placed approximately 10 m apart. A trap consisted of a 14 cm diameter by 12 cm deep plastic cup set into the ground so that the lip of the cup was level with the soil surface. Cups contained approximately 100 ml of a 50:50 mixture of ethylene glycol and water. Cups were covered by a 22 cm diameter plastic plate to reduce evaporation of preservative. A 2–3 cm space was left between the cover and the soil surface to allow arthropods to easily enter traps.

For black lighting, on three occasions over a one week period in June of 1996 five black-lights were spaced at approximately 50 m intervals throughout a site (ca. 2000 m^2) in the Red Hills Recreational Area. Lights were turned on around 9 pm and allowed to shine against a 1 m^2 white sheet. We sampled lights at 10 pm, 11 pm, and 12 am. During a collecting bout, arthropods were arbitrarily collected for approximately 5–10 minutes at each light.

Species-Specific Sampling: Streptanthus Polygaloides.—Accompanying the broad community-level sampling of the Red Hills, we also specifically sampled the arthropods associated with *S. polygaloides*, the only known Ni hyperaccumulator in the Red Hills. *Streptanthus polygaloides* is endemic to serpentine barrens of the foothills of the western part of the Sierra Nevada from Fresno County, California north to Butte County, California (Kruckeberg 1984). Containing an

average of 9750 $\mu\text{g Ni/g}$ (Reeves et al. 1981, Kruckeberg & Reeves 1995), *S. polygaloides* is an annual that often grows in relatively dense stands.

Streptanthus polygaloides was sampled via both sweep-netting and visual inspection. Sampling took place during June of 1996, 1997, and 1998 while the plants were in flower. Dense pure stands of *S. polygaloides* were targeted for sweep-netting in order to reduce inadvertent sampling of other plant species.

Apis mellifera L. and *Bombus vandykkee* (Frison) were used to compare Ni concentrations found within members of the same species that occur both on and off serpentine soils. Both species were collected from *S. polygaloides* in the Red Hills and from *Heteromeles arbutifolia* (Lindley) Roemer, a shrub growing on a nonserpentine site > 15 km from the Red Hills, for comparison.

Elemental Analysis.—Specimens were sorted according to morphotype and representatives of each morphotype were pinned and labeled for later identification to the lowest taxonomic level that could be readily attained. Individual specimens were air-dried for at least 72 h at 67° C and weighed. Individuals of the same morphotype weighing less than 50 mg were combined in order to create samples of at least that mass for analysis. Specimens were then analyzed for Ni concentration as described below. In order to sample variation in Ni values adequately, we analyzed at least three samples of each morphotype to generate means ($\pm$ SD). Many of our morphotypes could not be analyzed for Ni concentration, due to their low mass. Morphotypes with insufficient biomass to create three samples for analysis are not included in the data presented here.

Nickel concentration was determined with an atomic absorption spectrophotometer (Instrumentation Laboratory, IL 251). Samples were digested in borosilicate glass test tubes using 3–5 ml of concentrated nitric acid at 110° C for 6–8 h, after which time most of the liquid had evaporated. The residue was then redissolved in 3–5 ml of 1 M hydrochloric acid at 110° C for 2–4 h. The solutions were then diluted with distilled water to a volume of 10 or 25 ml, depending on the original mass of the dried sample. Reagent blanks were made and processed with every batch of samples in order to correct for any contamination generated by the technique. All metal values are reported as $\mu\text{g metal/g}$ on a dry weight basis.

Specimens containing unusually high levels of Ni (> 300 $\mu\text{g Ni/g}$) were also analyzed for Cr in order to rule out contamination by soil. Chromium levels are several orders of magnitude higher in serpentine soils than in the plants growing on serpentine soils. Unusually high levels of Ni accompanied by high levels of Cr indicate the potential of soil contamination (Brooks 1987). Concentrations of Cr were determined via inductively coupled argon plasma spectrophotometry (Jarrell-Ash, ICAP 9000).

Data Analysis.—Nickel concentrations in arthropod tissues were analyzed by one-way analysis of variance (ANOVA) in order to determine if association with *S. polygaloides* influenced specimen Ni concentrations. Nickel concentrations were log-transformed in order to satisfy the assumptions of ANOVA (Zar 1984). Log-transformed Ni concentrations of hemipteran herbivores collected on *S. polygaloides* were also analyzed via one-way ANOVA. In this case, post-hoc mean separations were performed using Fisher's Protected Least Significant Difference (PLSD) test (SAS Institute 1998) in order to compare Ni concentrations between pairs of hemipteran species. Vouchers of analyzed specimens were deposited in

Table 1. Nickel concentration (mean $\pm$ SD) of insect species or morphospecies associated with *Streptanthus polygaloides* in the Red Hill Recreational Area, California.

Order Family	Morphospecies or species	Mean $\pm$ SD	<i>n</i>
Coleoptera			
Bruchidae	<i>Acanthoscelides seminulum</i> Horn	55 $\pm$ 96	3
Melyridae	Mel-1	129 $\pm$ 18	3
Diptera			
Otitidae	Oti-1	58 $\pm$ 8	3
Hemiptera			
Miridae	<i>Melanotrichus boydi</i> Schwartz & Wall	777 $\pm$ 162	8
	<i>Lygus hesperus</i> Knight	131 $\pm$ 126	3
Pentatomidae	<i>Thyanta pallidovirens</i> (Stål)	40 $\pm$ 28	3
Rhopalidae	<i>Liorhyssus hyalinus</i> (Fabricus)	48 $\pm$ 50	4
Hymenoptera			
Apidae	<i>Apis mellifera</i> L.	43 $\pm$ 24	10
	<i>Bombus vandykei</i> (Frison)	38 $\pm$ 34	10
Halictidae	<i>Dialictus</i> sp.	51 $\pm$ 27	3
Lepidoptera			
Lycaenidae	<i>Everes amyntula</i> (Boisduval)	36 $\pm$ 34	3
Overall Mean		128 $\pm$ 218	

the University of Connecticut insect collection with voucher labels with the prefix, “wall-boyd-CA” followed by the morphospecies names listed in Tables 1 and 2.

RESULTS

We collected a total of 110 morphotypes of arthropods. Almost half of these arthropods (50) were collected in association with *S. polygaloides*. The remaining arthropods (60) were collected by black-lighting and pitfall-trapping. Of all the morphotypes collected, only 33 were collected in great enough number to allow us to analyze three replicates. Eleven of the 33 analyzed morphotypes were collected in association with *S. polygaloides*. The arthropods analyzed contained an average of 65 $\pm$ 132 μ g Ni/g. However, one plant bug associated with *S. polygaloides*, *Melanotrichus boydi* Schwartz and Wall, contained an average of 777 $\pm$ 162 μ g Ni/g (Table 1) (also see Schwartz and Wall 2001). *Melanotrichus boydi* contained almost no Cr (1 $\pm$ 2 μ g Cr/g, *n* = 3). If samples of *M. boydi* are excluded, the average Ni content of the arthropods sampled decreases to 43 $\pm$ 34 μ g Ni/g.

Nickel content of arthropods associated with *S. polygaloides* (Table 1) was significantly higher than the Ni content of arthropods collected via black-lighting and pitfall-trapping (Table 2, ANOVA: *F* = 11.45; *df* = 1, 31; *P* = 0.002). Even when *M. boydi* is excluded from this analysis, there is still significantly more Ni in arthropods associated with *S. polygaloides* than in arthropods collected via black-lighting and pitfall-trapping (ANOVA: *F* = 8.69; *df* = 1, 30; *P* = 0.006).

Melanotrichus boydi contained more Ni than other hemipteran herbivores found feeding on *S. polygaloides*. Other than *M. boydi*, three other hemipteran herbivores were collected from *S. polygaloides* in great enough numbers to analyze: *Lygus hesperus* Knight (Heteroptera: Miridae), *Thyanta pallidovirens* (Stål) (Heteroptera: Pentatomidae), and *Liorhyssus hyalinus* (F.) (Heteroptera: Rhopalidae).

Table 2. Nickel concentrations (mean $\pm$ SD) of insect species or morphotypes collected via pitfall traps and black lights in the Red Hills Recreational Area, California.

Order Family	Morphospecies or species	Mean $\pm$ SD	<i>n</i>
Coleoptera			
Elateridae	Ela-1	41 $\pm$ 69	3
Eucnemidae	Euc-1	23 $\pm$ 15	3
	Euc-2	19 $\pm$ 15	3
Tenebrionidae	<i>Eleodes</i> sp.	75 $\pm$ 71	3
Lepidoptera			
Geometridae	Geo-1	7 $\pm$ 7	3
	Geo-2	8 $\pm$ 14	3
	Geo-3	13 $\pm$ 23	3
	Geo-4	62 $\pm$ 80	3
	Geo-5	13 $\pm$ 16	3
	Geo-6	11 $\pm$ 13	3
	Geo-7	13 $\pm$ 12	3
Noctuidae	Noc-1	40 $\pm$ 59	3
	Noc-2	32 $\pm$ 24	3
Pyralidae	Pyr-1	12 $\pm$ 21	3
	Pyr-2	44 $\pm$ 69	3
	Pyr-3	12 $\pm$ 22	3
Neuroptera			
Corydalidae	Cor-1	32 $\pm$ 21	3
Myrmeleontidae	Myr-1	13 $\pm$ 7	3
Orthoptera			
Acrididae	<i>Malanopus</i> sp.	40 $\pm$ 15	5
Gryllacrididae	<i>Ceuthophilus</i> sp.	51 $\pm$ 28	3
Gryllidae	<i>Gryllus assimilis</i> (Fabricius)	133 $\pm$ 77	3
Tettigoniidae	<i>Arethea</i> sp.	55 $\pm$ 28	4
Overall Mean		34 $\pm$ 29	

All of these insects were observed feeding on the young stems and leaves of *S. polygaloides* in the field. Also, the presence of nymphs of *L. hesperus*, *M. boydi*, and *T. pallidovirens* on *S. polygaloides* supports the hypothesis that *S. polygaloides* can be a host for these herbivores. These herbivores varied significantly in Ni content (ANOVA: $F = 8.36$; $df = 3, 15$; $P = 0.002$). Although all these herbivores appeared to be feeding on *S. polygaloides*, *M. boydi* contained significantly more Ni than the other three species of hemipterans (Fisher's PLSD test: $P = 0.001, 0.008$, and 0.002 for pairwise comparisons of *M. boydi* with *L. hesperus*, *T. pallidovirens*, and *L. hyalinus* respectively).

Apis mellifera collected while visiting flowers of *S. polygaloides* contained significantly higher levels of Ni ($46 \pm 8 \mu\text{g Ni/g}$, $n = 10$) than those collected from *Heteromeles arbutifolia* ($16 \pm 8 \mu\text{g Ni/g}$, $n = 10$) in a non-serpentine environment (ANOVA: $F = 7.88$; $df = 1, 18$; $P = 0.012$). Like *A. mellifera*, *Bombus vandykei* collected from *S. polygaloides* contained significantly more Ni ($38 \pm 15 \mu\text{g Ni/g}$, $n = 5$) than those collected from *H. arbutifolia* ($12 \pm 14 \mu\text{g Ni/g}$, $n = 5$); (ANOVA: $F = 8.60$; $df = 1, 8$; $P = 0.019$).

DISCUSSION

Historically, little attention has been paid to accumulation of Ni by arthropods in terrestrial environments (see Hopkin 1989). This may be due to the typically

low levels of Ni found in arthropods from metal-contaminated sites (e.g., Helioväara and Vaisanen 1990, Helioväara et al. 1990, Bagatto and Shorthouse 1996). On the other hand, a study of arthropods collected from serpentine sites in Zimbabwe reported very high levels of Ni accumulation (Wild 1975). Termites collected from these sites contained 5000 $\mu\text{g Ni/g}$ and 1500 $\mu\text{g Cr/g}$ (Wild 1975). Wild (1975) hypothesized that these high levels of Ni and Cr were the result of accumulation from ingested plant material. In plant material, however, high levels of Cr are typical of soil contamination on specimens (Brooks 1987). As with Wild's (1975) work with termites from the serpentine exposures of Zimbabwe, there is the potential that residual plant material in the gut and/or dust on specimens may have artificially elevated Ni concentrations in *Melanotrichus boydi*. Soil/dust contamination is unlikely unless Cr concentrations in a sample exceed 100 $\mu\text{g Cr/g}$ (Brooks 1987). Levels of Cr in *M. boydi*, averaging only 1 $\mu\text{g Cr/g}$, are extremely low and thus soil/dust contamination seems unlikely to be the source of Ni in the specimens analyzed.

There are several alternatives that may explain the disparity in Ni content found amongst herbivores of *Streptanthus polygaloides*. In one scenario, metal content varies between tissues and organs of the plant and the observed differences in herbivore metal content simply reflect the differences in the plant tissue or organ type upon which was fed. In this study, the herbivores with the three lowest Ni values, *Thyanta pallidovirens*, *Liorhyssus hyalinus*, and *Acanthoscelides semimulum*, were collected on the developing fruits of *S. polygaloides*. Indeed, the developing fruits (1100–5230 $\mu\text{g Ni/g}$) of *S. polygaloides* are known to contain less Ni than leaves (3300–14,800 $\mu\text{g Ni/g}$) or flowers (2860–16,400 $\mu\text{g Ni/g}$) (Reeves et al. 1981). On the other hand, both mirid species, *M. boydi* and *Lygus hesperus*, feed on the same plant organs, young developing leaves and flowers. Thus it is difficult to explain the disparity in metal content of the two mirids, as being due to differences in organ metal content. These differences could, however, be due to variation in metal content between tissues. Boyd and Martens (1999) found that aphids were able to feed upon *S. polygaloides* without accumulating significant amounts of Ni. The implication being that the aphids contained little Ni because the phloem sap contains little Ni. Unlike aphids, no mirids are known to tap into sieve elements and feed directly on phloem sap (Wheeler 2001). While feeding on phloem sap is unlikely to explain the low metal content in *L. hesperus* relative to *M. boydi*, the two species could target tissues of differing metal content within *S. polygaloides*. Unfortunately, nothing is known about the distribution of metal between tissues in *S. polygaloides*.

The alternative scenario is that these species feed on similar tissues but vary in their ability to accumulate and/or excrete metal. If the insects are unable to avoid metal, then excretion and storage-detoxification are the two major strategies for terrestrial invertebrates dealing with toxic levels of heavy metal (Dallinger 1993). To effectively distinguish which strategy is employed by which species would require laboratory-based studies with artificial diets as opposed to our own field-based studies. It is interesting to note, however, that previous work has shown *M. boydi* to be a specialist on *S. polygaloides* (Wall 1999) and *L. hesperus* is widely known to be extremely polyphagous (Schwartz & Footit 1998). Thus differences in strategy may represent different "trade-offs" by specialist versus polyphagous herbivores (Futuyma & Moreno 1988).

We found that arthropods associated with a Ni hyperaccumulator, *S. polygaloides*, contained more Ni than arthropods collected from the general serpentine community. Arthropods collected from *S. polygaloides* also contained more Ni than arthropods reported in the literature that were collected from sites contaminated with Ni (e.g., Helioväara and Vaisanen 1990, Helioväara et al. 1990). The higher levels of Ni found in arthropods associated with *S. polygaloides* probably reflect the degree to which hyperaccumulators accumulate Ni, as well as the bioavailability of that Ni. Although plants from Ni-contaminated sites typically contain relatively low levels of Ni (e.g., Koricheva and Haukioja 1995), *S. polygaloides* contains an average of 9750 $\mu\text{g Ni/g}$ (Reeves et al. 1981). Often, Ni contamination at polluted sites is the result of aerial deposition and therefore is only available in an inorganic form (Berthelsen et al. 1995). Within hyperaccumulators, Ni appears to be complexed with an organic acid (Lee et al. 1978) and is potentially more available to arthropods.

The variation in metal content that we observed within insect orders highlights the need to separate taxa to finest taxonomic level that material allows. In their study on metal content of insects associated with Scottish serpentine soils, Davison et al. (1999) pool their specimens together at the ordinal level for metal analysis. This does not allow exploration of intraordinal variation in metal content, which our study suggests, can be significant. For instance, mean values of Ni within the Hemiptera ranged from $40 \pm 28 \mu\text{g Ni/g}$ in *T. pallidovirens* to $777 \pm 162 \mu\text{g Ni/g}$ in *M. boydi*. From this perspective, our own study would have been more informative had we the biomass to analyze different body parts in order to isolate Ni localization within the body.

The variation of Ni content that we observed in this study offers a unique system upon which comparative studies can be built. For instance, both an endemic specialist (i.e., *M. boydi*) and cosmopolitan generalists (e.g., *T. pallidovirens*, and *L. hesperus*) feed on *S. polygaloides*. These two groups differ significantly in metal content (Table 1), yet the function of elevated Ni content in *M. boydi* and the physiological mechanisms by which it sequesters Ni remain unclear. Research that contrasts the physiological mechanisms of metal tolerance in *M. boydi* with those of generalist herbivores could address both of these issues.

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OVIPOSITION PREFERENCES OF *SCIRTOTHRIPS PERSEAE* NAKAHARA (THYSANOPTERA: THRIPIDAE) IN SOUTHERN CALIFORNIA AVOCADO ORCHARDS

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Abstract.—A survey was conducted over the period July 1998–1999 to determine the oviposition preferences of female *Scirtothrips perseae* in a southern California avocado orchard. Female thrips oviposited into the undersides and topsides of immature avocado leaves, small fruit, and petioles from immature fruit. A significant oviposition hierarchy was determined with immature fruit being most preferred for oviposition followed by undersides of immature leaves, immature fruit petioles, and the topsides of immature leaves. Immature leaf petioles and stems were not used for oviposition. Of field collected fruit, small fruit 25–54 mm in length were most preferred for oviposition as fruit in this size range, on average, had the greatest mean numbers of *S. perseae* larvae emerging from them. The results of this work have important applications for the development of integrated pest management (IPM) programs using carefully timed natural enemy releases and pesticide applications to reduce low-density *S. perseae* populations before fruit of a size vulnerable to thrips feeding damage is set on trees.

Key Words.—Insecta *Scirtothrips perseae*, *Persea americana*, avocado, oviposition preference.

Scirtothrips perseae Nakahara (Thysanoptera: Thripidae) is a new pest of avocados (*Persea americana* Mill. [Lauraceae]) in California USA, and at time of discovery this insect was a species new to science (Nakahara 1997). Populations of *S. perseae* were first found in June 1996 damaging avocado fruit and foliage in Saticoy and Oxnard, Ventura County, and later around Irvine, Orange County, both in California. By July 1997, infestations of *S. perseae* were north of the initial discovery areas into San Luis Obispo County and south into San Diego County (Hoddle & Morse 1997). This pest is native to Mexico and Guatemala, and in California, *S. perseae* has only been found feeding on avocados suggesting that this thrips has a highly restricted host range (Hoddle et al. 2002).

Scirtothrips perseae builds to high densities on immature avocado foliage and cumulative feeding damage by larvae and adults can induce premature defoliation by mid to late spring. Thrips larvae and adults feeding on immature fruit are the primary cause of economic damage to avocados in California. Feeding damage results in brown scarring to fruit skin as it matures. Heavily infested orchards in Ventura County experienced 50–80% crop damage in 1997, and much of the damaged fruit was either unmarketable or downgraded in packinghouses. In 1998, crop losses due to damaged fruit that were downgraded and increased production costs due to insecticide use to control *S. perseae*, cost the California avocado industry approximately \$7.6–13.4 million (US) (Hoddle et al. 1998, 1999).

Little is known about the developmental and reproductive biology, and field ecology of *S. perseae* in its native range or California. The purpose of this work was to determine what substrates are most preferred for oviposition by *S. perseae* in avocado orchards. Improved understanding of the egg-laying choices by females may assist in timing natural enemy releases or pesticide applications to protect the most preferred oviposition substrates. Optimizing treatment timing

may maximize control impact and reduce the number of spray applications needed to prevent thrips from causing economic damage.

MATERIALS AND METHODS

Study Site.—A commercial 40 ha ‘Hass’ avocado orchard (85% of fruit production in California is from the ‘Hass’ cultivar) in Bonsall, San Diego County, California, USA (33°16.45 N, 117°13.09 W, elevation 124 m) was selected for this study. This orchard had a very heavy *S. perseae* infestation when surveys were conducted over the period July 1998–July 1999. No sprays were applied for thrips control over this time period. The orchard was located in plant climate zone 2S (southern coastal valley [Kimball & Brooks 1959]) and subject to a moderating marine influence.

Surveying Potential Oviposition Sites.—Potential oviposition substrates used by *S. perseae* were investigated by collecting $\frac{3}{4}$ expanded avocado leaves, young green twigs from terminal branches, petioles from $\frac{3}{4}$ expanded leaves, immature fruit, and fruit petioles from the study site. Plant parts were measured, placed on foam pads saturated with water in stainless steel trays, and held in temperature cabinets at 25° C under long days (L:D 14:10). Glass cells (2.8 cm diameter, 1.5 cm height) with the top opening covered with polyester mesh (95 micron openings) were adhered to upper leaf and lower leaf surfaces with Duco® Stik-Tak (Devcon Consumer Product, Illinois, USA) to trap emerged larvae. Plant parts were examined daily, and numbers of emerged *S. perseae* larvae were recorded for seven consecutive days following field collection.

Emergence of Larvae from Immature Avocado Leaves.—Mean numbers of larvae emerging from immature leaves and percentage infested leaves were determined by making weekly collections of 20 leaves at the study site from July 1998–March 1999. Leaves were placed upper side down on water-saturated foam pads in stainless steel trays and held at 25° C under long days (L:D 14:10) in temperature controlled cabinets. Larval emergence per leaf was recorded daily for seven days.

Determining Avocado Fruit Size Preferences for Oviposition.—Substantial off bloom over the summer of 1998 supplemented normal fruit production in spring 1999 and resulted in significant numbers of fruit in all size categories being present over the course of this survey. Immature avocados were picked weekly from fruit bearing trees at the study site. A total of 1066 fruit were collected from 29 January 1999 to 12 July 1999. Harvested fruit were numbered, and per fruit lengths (mm) and diameters (mm) were recorded. Fruit were adhered to the bottoms of stainless steel pans with Duco® Stik-Tak, and pans were partially filled with water to prevent *S. perseae* larvae leaving fruit from which they had emerged. Fruit in pans were placed in temperature controlled cabinets at 25° C under long days (L:D 14:10) and numbers of emerged larvae per fruit were recorded and removed with a moistened paint brush daily for seven consecutive days. Fruit were placed in one of 15 size categories based on length. The mean number of emerged larvae, and percentage of fruit infested with *S. perseae* in each size category were calculated.

Statistical Analyses.—Numbers of *S. perseae* larvae emerging from potential oviposition substrates were compared using Log-likelihood Ratio Test (i.e., G-test) to determine if substrate preferences for oviposition existed. Pair-wise com-

Table 1. Total number of emerged *Scirtothrips perseae* larvae from potential oviposition substrates. Collected plant material was incubated at 25°C for seven days. Numbers followed by italicized Roman numerals are significantly different from each other.

Oviposition substrate	Size (cm) ± SE	n	No. emerged larvae
Young leaf petioles	5.95 ± 0.12 ^a	40	0
¾ Expanded avocado leaves (tops)		52	4 <i>i</i>
¾ Expanded avocado leaves (bottoms)		51	78 <i>ii</i>
Thin green stems	0.75 ± 0.06 ^b	40	0
Thick green stems	1.47 ± 0.10 ^b	40	0
Immature fruit	2.85 ± 0.17 ^b	15	43 <i>iii</i>
Immature fruit petioles	9.90 ± 0.54 ^a	15	5 <i>iv</i>

^a Mean length.
^b Mean diameter.

parisons between substrates from which larvae emerged were made using χ^2 as sample sizes were large (Sokal and Rohlf 1995). Numbers of *S. perseae* larvae emerging per fruit in each size category were log-transformed and mean numbers of emerged larvae were compared across size categories using ANOVA in SAS (SAS 1990) with Tukey’s Studentized Range Test at the 0.05 level of significance being used for means separation.

RESULTS

Oviposition Preferences.—*Scirtothrips perseae* larvae emerged from the tops and bottoms of immature avocado leaves, immature fruit, and the petioles attached to collected fruit. Significant differences in larval emergence from different oviposition substrates were observed ($\chi^2_3 = 131.28$; $P < 0.001$). Significantly more *S. perseae* larvae emerged from immature fruit ($\chi^2_1 = 10.17$; $P = 0.001$) followed by emergence from the undersides of immature leaves ($\chi^2_1 = 17.25$; $P < 0.001$) > immature fruit petioles ($\chi^2_1 = 4.63$; $P = 0.031$) > topsides of immature leaves. Immature leaf petioles and stems were not used for oviposition (Table 1).

Larval Emergence Patterns from Immature Leaves.—Larval emergence from immature leaves declined to very low levels from August to mid November 1998. Emergence rates peaked at the end of February 1999 at 33.18 ± 10.05 emerged larvae (range 0–189 emerged larvae per leaf) per leaf and declined by approximately 50% to 15.58 ± 2.73 larvae per leaf in early April 1999 (Fig. 1A). During periods of very low larval thrips emergence, percentage of infested leaves reached zero on only four occasions, twice in September and November 1998 (Fig. 1B).

Fruit Size Preferences for Oviposition.—*Scirtothrips perseae* larvae emerged from 55.66% of 1066 fruit that were 4–96 mm in length. Significant differences in mean numbers of larvae emerging from each fruit size category ($F_{(14,1045)} = 45.75$; $P < 0.0005$) (Fig. 2A). The largest mean number (34.63 larvae per fruit ± 5.27 [SE]) of larvae per fruit emerged from fruit in the 40–44 mm length category and the lowest number of thrips larvae emerged from fruit >75 mm in length (0.05 larvae per fruit ± 0.04 [SE]) were observed (Fig. 2A). The highest percentage of infested fruit were 40–44 mm in length (94.37%) and the least infested fruit category (4.11%) were >75 mm in length (Fig. 2B).

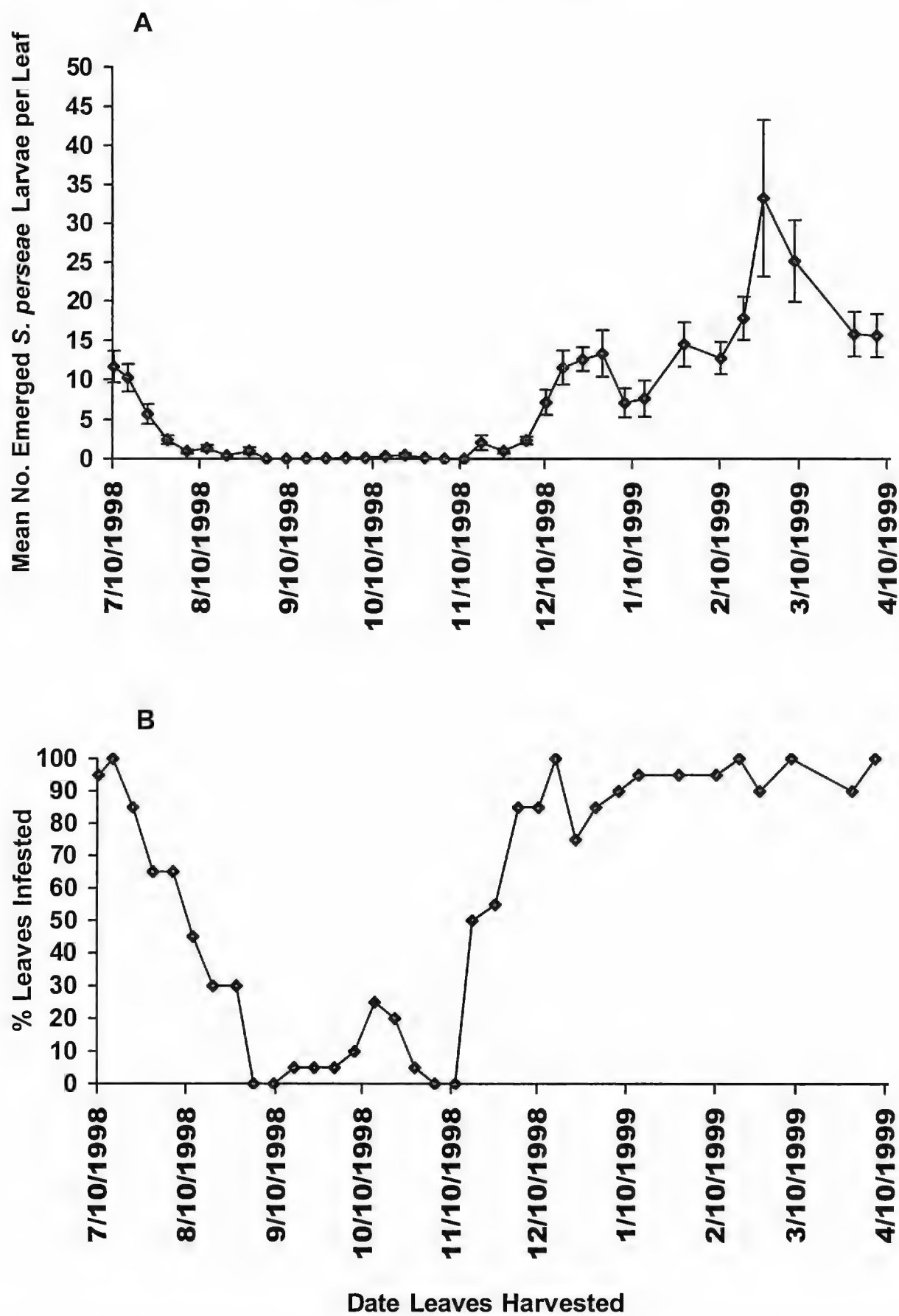


Figure 1. (A) Mean number ($\pm$ SE) of emerged *Scirtothrips perseae* larvae per leaf and (B) percentage of leaves from which *S. perseae* larvae emerged for leaves collected at Bonsall, California.

DISCUSSION

Scirtothrips perseae females preferentially oviposited into immature avocado fruit, with the undersides of immature avocado leaves being the next highly preferred oviposition site when these two substrates were simultaneously available. Upper surfaces of immature leaves and immature fruit petioles were the least favored oviposition substrates and no larvae were recovered from immature leaf

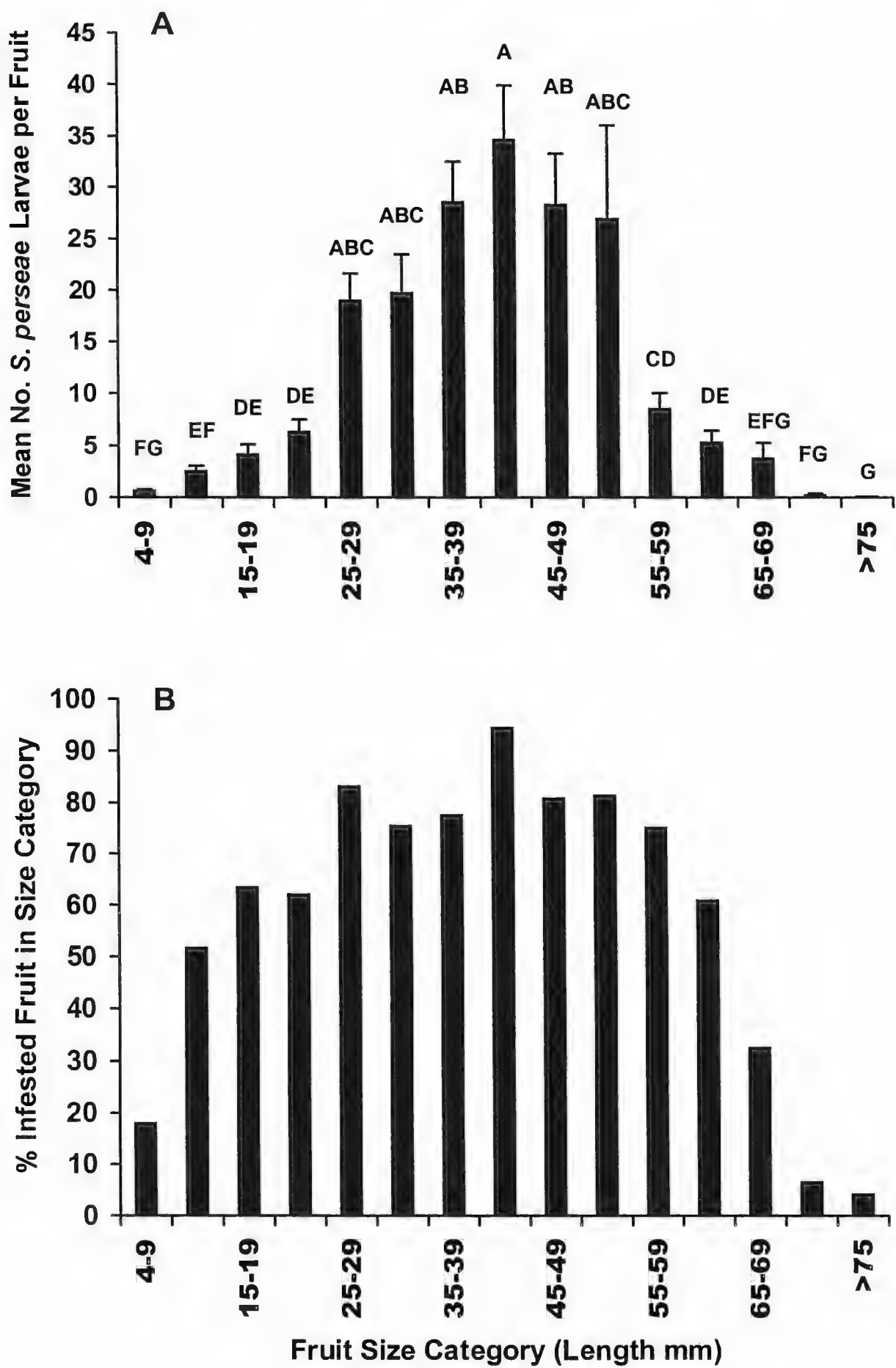


Figure 2. (A) Mean number ($\pm$ SE) of emerged *Scirtothrips perseae* larvae per fruit length category, and (B) percentage of fruit in each length category from which *S. perseae* larvae emerged.

petioles and green twigs indicating that egg-laying females do not utilize these structures.

Significantly more *S. perseae* larvae emerged from field-collected fruit 25–54 mm in length than other size categories. Avocados spontaneously abort ~90% of fruit <10 mm in length (Yee et al. 2001a) and selection of fruit by female *S. perseae* in the size range 25–54 mm is probably under strong selection pressure

as the feeding resource selected for larvae by females needs to be mature enough to remain on trees, yet tender enough to permit oviposition and sufficient larval feeding time for immature thrips to complete development before fruit skin is too thick to feed on (i.e., fruit >55 mm in length). Field observations indicate that *S. perseae* is most commonly found on fruit 20–40 mm in length, and most economic scarring occurs over a two week period when fruit 5–14 mm retained by trees are used for feeding by adult and immature thrips (Yee et al. 2001ab).

Emergence of *S. perseae* larvae from field collected leaves over July–August and November–March suggests that large founding populations of thrips could be accidentally imported into the USA on smuggled plant material. Work on *Sericothrips staphylinus* Haliday (Thysanoptera: Thripidae) used for the biological control of *Ulex europaeus* (L.), a noxious weed in New Zealand, has demonstrated that 33% of carefully managed releases of just 10 adult thrips into a permissive environment can result in establishment and proliferation (Memmott et al. 1998). On average, more than 10 larval *S. perseae* per leaf emerged over October–March in this study suggesting that individual leaves may harbor enough thrips eggs to found incipient populations.

As part of an IPM program being developed for *S. perseae* in California, monitoring of low-density pest populations and application of carefully timed insecticide sprays with high selectivity towards thrips on immature foliage during the pre-bloom period is being investigated. The results of this oviposition preference study suggest that proactive pesticide applications or natural enemy releases (e.g., *Franklinothrips orizabensis* Johansen [Thysanoptera: Aeolothripidae] [Hoddle et al. 2000, 2001a, b]) on trees with immature leaves in spring prior to fruit set may help to selectively protect the most preferred oviposition and larval feeding sites from *S. perseae*.

ACKNOWLEDGMENTS

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THE DISCOVERY OF THE GENUS *GNAMPTODON* HALIDAY (HYMENOPTERA: BRACONIDAE) IN CHINA, WITH DESCRIPTION OF ONE NEW SPECIES

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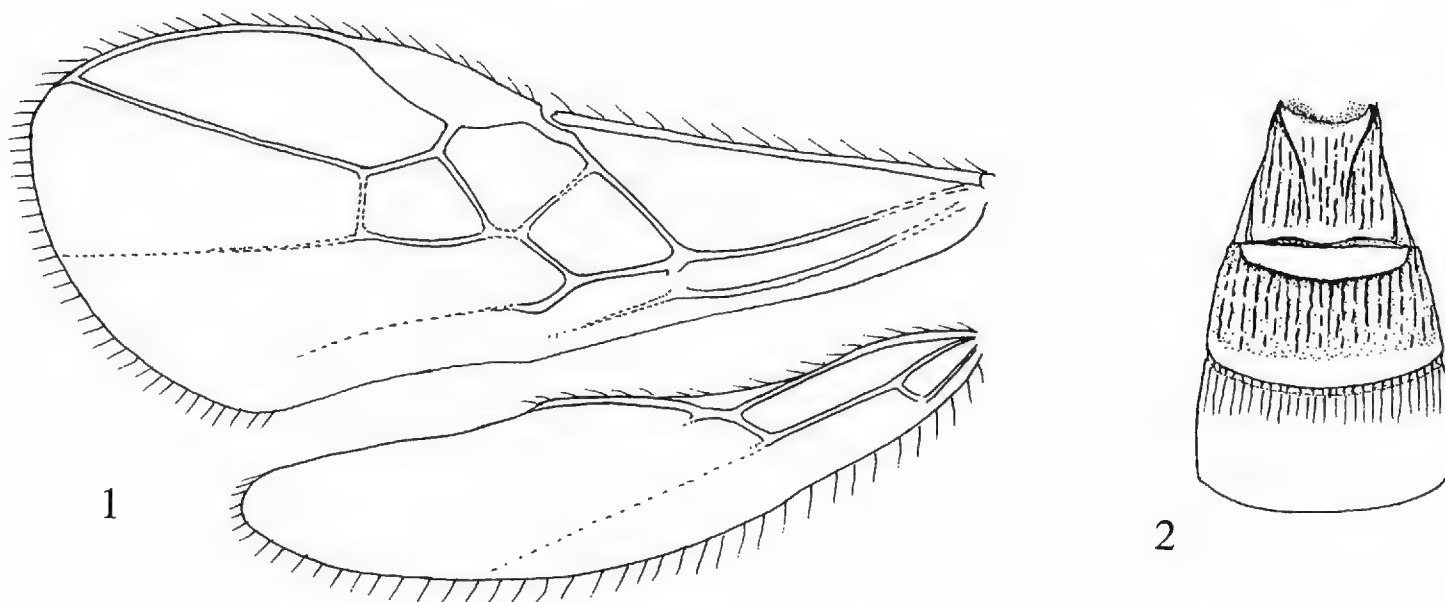
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Abstract.—Two species of *Gnamptodon* are reported in this paper from China including one new species, *Gnamptodon chinensis* sp. nov. It represents the first record of the genus *Gnamptodon* as well as the subfamily Gnamptodontinae in China.

Key Words.—Insecta, Hymenoptera, Braconidae, Gnamptodontinae, *Gnamptodon*, Braconidae, new species, China.

The genus *Gnamptodon* Haliday contains some of the smallest Braconidae, usually scarcely longer than 1 mm, which are exclusively parasitoids of the mining caterpillars of Nepticulidae (Lepidoptera). Thirty seven species, i.e., 15 Palearctic, 7 Nearctic, 3 Oriental, 8 Australian, 3 Afrotropical and 1 Neotropical, have been described worldwide at present (van Achterberg 1983, 1988; Belokobylskij 1987; Narendran & Rema 1996; Papp 1996, 1997; Tobias & Saidov 1997). There were no species recorded in China before this study, although several species have been reported from adjacent countries, such as *G. orientalis* van Achterberg from Thailand, *G. nepalicus* Fischer from Nepal, *G. indicus* Narendran & Rema and *G. malabaricus* Narendran & Rema from India, and *Gnamptodon georginae* van Achterberg from the Russian Far East. The species of this genus seem in general to be rarely collected. Only five specimens were found during this study after the first author examined all of the most important collections in China, including the Parasitic Hymenoptera Collection in Zhejiang University (which started in the 1920s and contains about 0.5 million pinned specimens, and as many specimens in alcohol) and the insect collections of Academia Sinica in Beijing and Shanghai. Two species of *Gnamptodon* are recognized in this paper from China, including one new species, *Gnamptodon chinensis* sp. nov., from the Oriental part of the country. It represents the first record of the genus *Gnamptodon* as well as of the subfamily Gnamptodontinae in China. Specimens of the two Chinese species were collected by sweep net, and therefore there is no host record.

The subfamily Gnamptodontinae contained 4 genera originally, i.e., *Gnamptodon* Haliday, 1837 (cosmopolitan), *Pseudognaptodon* Fischer, 1965 (New World), *Gnaptogaster* Tobias, 1976 (Palearctic) and *Liparophleps* Enderlein, 1920 (Neotropical) (van Achterberg 1983). *Liparophleps* has subsequently been determined to represent a junior synonym of *Semirhytus* Szépligeti (Doryctinae), and thus has been removed from Gnamptodontinae (Marsh 1976, Wharton 1997). Recently Belokobylskij (1999) described another monotypic genus, *Neognamptodon* Belokobylskij, 1999 of the subfamily from Madagascar. Only the biology of *Gnamptodon* and *Pseudognaptodon* is known; both are parasitoids of nepticulid



Figures 1–2. *Gnamptodon chinensis* sp. nov., holotype. 1, wings. 2, first–third metasomal tergites, dorsal view.

larvae, but it is not yet definitively demonstrated whether they are endo- or ectoparasitoids.

For the identification of the genus *Gnamptodon* Haliday, see van Achterberg (1983). For the terminology used in this paper, see van Achterberg (1993) and Chen & He (1997). The type specimen is deposited in the Hymenoptera Collection, Zhejiang University, Hangzhou, China (ZJU).

GNAMPTODON CHINENSIS CHEN & WHITFIELD, NEW SPECIES

Gnamptodon chinensis sp. nov. (Figs. 1 and 2)

Description.—Female: body length 1.5 mm, fore wing length 1.5 mm.

Head: Antennal segments 19, length of third segment 1.2 times fourth segment, length of third, fourth and penultimate segments 3.3, 2.8 and 2.6 times their width respectively; length of eye 2.3 times temple in dorsal view; POL: OD: OOL = 4:2:9; frons virtually flat and distinctly granulate; vertex concave and smooth; face distinctly convex and smooth, with long setae; length of malar space 1.6 times basal width of mandible.

Mesosoma: Length of mesosoma 1.6 times its height; mesosoma smooth; mesoscutal lobes nearly glabrous, without medial depression; scutellar sulcus narrow and finely crenulate.

Wings: Fore wing. r: 3-SR: SR1 = 4:12:48; 1-CU1: 2-CU1 = 2:16; 2-SR: 3-SR: r-m = 16:12:10; length of pterostigma 0.7 times vein 1-R1; length of distance between apex of wing and apex of marginal cell 0.2 times vein 1-R1; pterostigma robust; vein SR1 nearly straight.

Legs: Length of femur, tibia, and basitarsus of hind leg 3.6, 7.0 and 4.0 times their width respectively.

Metasoma: Length of first tergite equal to its apical width, its surface distinctly longitudinally rugose, with dorsal carinae developed; curved transverse elevation of second tergite distinct and smooth, second tergite behind the transverse elevation distinctly longitudinally rugose, apical margin smooth; median length of elevation of second tergite 0.36 times median length of rest of tergite; second intersegmental suture of metasoma distinct, crenulate, with no additional grooves; third tergite basally longitudinally striate, rest of third tergite and following tergites smooth; ovipositor slightly curved downwards, with nodus subapically; length of sheath 0.08 times fore wing, 0.8 times hind basitarsus.

Color: Head yellowish brown, vertex darker; antenna brown, basal four segments yellowish; palpi yellow; mesosoma reddish brown, mesoscutum, scutellum and propodeum darker reddish brown; legs brownish yellow, tarsi and hind tibia yellow; metasoma darker reddish brown, ventrally, tergites 2–4 laterally and fifth and its following tergites brownish yellow. Wing membrane hyaline, pterostigma and veins brown.

Male: Unknown.

Material examined: holotype female, China: Zhejiang, Mt. Gutian, 1990.vii–viii, Ma Yun, no.905760.

Diagnosis.—This species is from the Oriental part of China and is similar to *G. orientalis* van Achterberg, 1983, but can be separated from the latter by having the frons distinctly granulate; scutellar sulcus finely crenulate; length of distance between apex of wing and apex of marginal cell of fore wing 0.2 times vein 1-R1; pterostigma robust; and first and second tergites distinctly longitudinally rugose. It is also similar to *G. pumilio* (Nees), but can be readily distinguished from the latter by the sculpture of the metasomal tergites. It also can be easily separated from the other known species from China, *G. georginae* van Achterberg, 1983, by having the much longer vein 1-R1 of the fore wing.

Gnamptodon georginae van Achterberg, 1983

Gnamptodon georginae van Achterberg, 1983, Tijdschrift voor Entomologie, 126(2): 33.

Material examined: 1 female, China: Liaoning, Dalian, 1991.ix.4, Lou Juxian, no.975981.

Distribution: China (Liaoning); Russia Far East, Algeria, Bulgaria, Switzerland, Hungary.

Note: This species is new to China.

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TWO NEW SPECIES OF *BETELGEUSE* FROM MEXICO (HYMENOPTERA: BRACONIDAE: EUPHORINAE)

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Abstract.—Two new species of euphorine Braconidae from Mexico, *Betelgeuse piceus*, NEW SPECIES and *Betelgeuse variabilis*, NEW SPECIES, are described and illustrated. A key to the three known species is included. The male of *B. variabilis* is described, and represents the first record of males for this genus. Previously all genera in the tribe Dinocampini were thought to reproduce via thelytokous parthenogenesis, with males being absent or extremely rare. Unusual variation of the fore wing vein Rs+M is documented and discussed.

Key Words.—Insecta, Braconidae, Euphorinae, Dinocampini, *Betelgeuse*, Mexico, new species.

The genus *Betelgeuse* (pronounced “beetle-juice”) was described by Shaw (1988) to include one Mexican species placed in the tribe Dinocampini. The genus is named after the star Betelgeuse in the constellation Orion (a sword-bearing hunter in Greek mythology), because the female wasp has a conspicuous sword-like ovipositor (Fig. 14). Despite its distinctive appearance and ease of recognition, specimens of *Betelgeuse* are extremely rare in collections. The purpose of this paper is to describe two new species of *Betelgeuse* based on material from the Canadian National Collection (Ottawa) and the California Academy of Sciences (San Francisco). Like the type-species of the genus, *Betelgeuse aztecus*, both new species also have females with serrate antennae and are known only from Mexico. Males are described for one of the new species, *B. variabilis*, this being the first record of males for the genus. Sexual dimorphism of the antenna is documented (Figs. 7 and 8). The same species also exhibits unusual variation of the fore wing vein Rs+M (Figs. 10–13).

MATERIALS AND METHODS

Betelgeuse species can be identified as members of the subfamily Euphorinae using the keys of Shaw (1995) or Sharkey (1997). Diagnosis of the genus *Betelgeuse* follows that of Shaw (1988). Specimens can be determined as *Betelgeuse* using the key provided by Shaw (1997). The genus is easily distinguished by its very coarse head (Fig. 1) and mesosomal sculpture, large propodeal tubercles (Fig. 14), and females with serrate antenna (Figs. 3–5). Members of this genus are the only known braconid wasps with serrate antennae.

The morphological terminology used here follows that of Sharkey and Wharton (1997). Fore wing venation terminology is illustrated in Fig. 9. Microsculpture terminology follows that of Harris (1979). Since specimens have the metasoma bent in different positions, body length was measured by adding the combined lengths of the head, mesosoma, and metasoma (excluding the ovipositor).

KEY TO FEMALE SPECIMENS OF *BETELGEUSE*

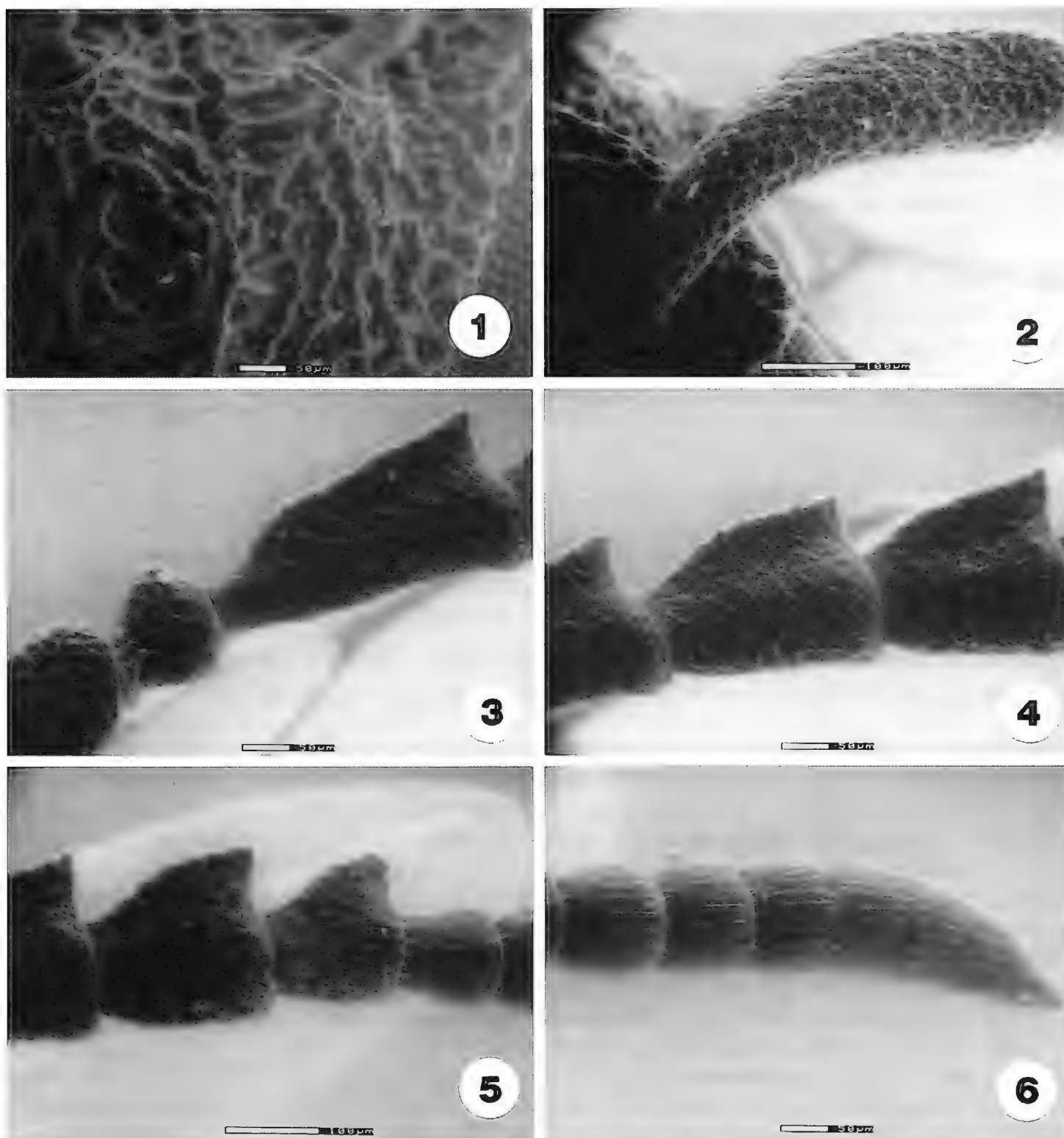
- 1a. Antenna with 13 flagellomeres (Fig. 14); apical flagellomere about 2× longer than preceding flagellomere; head and mesosoma mostly orang-

- ish brown; forewing with stigma dark brown; second subdiscal cell of forewing mostly clear or faintly infumate *Betelgeuse aztecus* Shaw
- 1b. Antenna with 9 flagellomeres (Fig. 7); apical flagellomere at least 3× longer than preceding flagellomere (Fig. 6); head and mesosoma mostly very dark brown or black; forewing with stigma nearly black; second subdiscal cell of forewing with a deeply infumate, very distinct, darkly pigmented patch (Figs. 9 and 10) 2
- 2a. Head and mesosoma black; cross-vein 1cu-a of forewing angled posteriorly towards wing base (Fig. 9) . . . *Betelgeuse piceus*, NEW SPECIES
- 2b. Head and mesosoma dark brown infumated with black; cross-vein 1cu-a of forewing vertical or angled slightly away from wing base (Fig. 10) *Betelgeuse variabilis* NEW SPECIES

BETELGEUSE PICEUS SHAW, NEW SPECIES
(Figs. 1–6, 9)

Types.—Holotype, female; data: MEXICO. Chis (= Chiapas), San Cristobal (de las Casas), 2200 m, 26–27 May 1990, H. Howden, B. Gill, FIT [deposited at Canadian National Collection, Ottawa]. Paratype: 1 female, same data as holotype [deposited at University of Wyoming Insect Museum, Laramie].

Description of Holotype Female.—Body length (excluding ovipositor) 6.0 mm; forewing length 3.3 mm. Head transverse, in dorsal view 2.1× broader than long; surface sculpture coarsely and evenly rugose (Fig. 1); eye elongate oval, not bulging anteriorly beyond face; eyes in anterior view distinctly converging ventrally; shortest inter-ocular distance 1.6× clypeus width; eye apparently glabrous; median frontal carina absent, obscured by rugose sculpture; inter-antennal distance 2.4× socket width; scrobes very slightly protuberant; scape elongate, gradually curved, gradually wider apically; scape length 4.4× width at apex (Fig. 2); pedicel somewhat globose (Fig. 3); flagellum 9-segmented, considerably shorter than body length; flagellomeres 1–5 longer than wide (Figs. 3–5), F1–F4 of similar width, F5 slightly less wide, F1–F5 somewhat flattened, forming serrations antero-laterally, each serration terminating apically in a point with a single large seta; F1 2.0× longer than apical width; F2–F5 each relatively shorter than preceding flagellomere; F6–F8 each compact, about as long as wide (Figs. 5 and 6); apical flagellomere (F9) 3.8× longer than wide, apically pointed (Fig. 6); ocellar triangle small, distance between lateral ocellus and compound eye 2.5× distance between lateral ocelli; occipital carina complete dorsally and somewhat crenulate, ventrally absent and not meeting hypostomal carina; malar space short, slightly greater than 1/3 eye height; malar suture absent; facial setae minute, not obscuring face; lower clypeal margin truncate; mandibles very sharply pointed, when closed overlapping for about 3/4 mandible length; maxillary palpus 5-segmented; labial palpus 2-segmented. Mesosoma with surface sculpture entirely coarsely rugose to rugo-punctate; notaulus and sternaulus indistinct from general rugose sculpture; scutellar furrow 8-foveate; anterior margin of scutellar furrow weakly carinate; scutellum large, triangular, and projecting posteriorly as a distinct conical point; propodeum with deep postero-median impression, as deep as basal width of petiole (metasomal tergum 1); postero-lateral corners of propodeum developed as broad lateral tubercles; petiolar notch short, not extending past metacoxal cavity; hind coxa rugose, remainder of leg coarsely granular; metafemur length 3.9× maximum width; tarsal claw simple. Fore wing with pterostigma large, nearly semi-circular; forewing vein 1M gradually and evenly curved; vein RS+Ma absent basally but present apically as very short stub (about 1/2 length of vein r); vein RS+Mb long and curved; vein 3RS entirely tubular and distinct, reaching wing margin well before wing apex; marginal cell shorter than pterostigma length (about 0.8× pterostigma length); vein r-m absent; vein M+CU slightly curved at middle; tubular portion of vein 2M about equal in length to vein r; vein 1CUa angled posteriorly at 110 degrees relative to vein M+CU; vein 2CU slightly longer than m-cu, curved apically; vein 1cu-a postfurcal by distance slightly greater than its length, angled posteriorly toward wing margin; vein 2-1A short and straight, about equal in length to 1Cub. Hind wing with 3 hamuli; vein RS absent basally but apically indicated by infumate line nearly reaching wing tip; vein 2M



Figures 1–6, scanning electron micrographs of *Betelgeuse piceus*, NEW SPECIES, 200 $\times$ magnification, anterior view. Figure 1. Coarse facial sculpture below antennal insertions. Figure 2. Antennal scape showing coarse sculpture. Figure 3. Pedicel and first antennal flagellomere. Figure 4. Second and third flagellomeres. Figure 5. Fourth to sixth flagellomeres. Figure 6. Seventh to ninth flagellomeres (antennal apex).

indicated by infumation nearly reaching lower wing margin; vein cu-a curved, meeting vein 1A posteriorly in a tubular joint, without obvious bulla or wing fold. Metasoma with petiole not fused ventrally, apex 2.9 $\times$ broader than base, about 0.6 $\times$ as long as metasoma beyond petiole (excluding ovipositor); tergum 1 rugose over basal $\frac{3}{4}$, smooth over apical $\frac{1}{4}$; glymma absent; dorsope absent; petiolar spiracles just beyond middle of petiole, barely prominent; syntergum 2+3 smooth and highly polished, about $\frac{3}{4}$ as long as petiole; lateral fold of syntergum 2+3 present; suture between terga 2+3 present laterally; terga 4–8 exposed beyond syntergum 2+3, all smooth and highly polished; tergum 8 short and strongly compressed to form a vertical slit above ovipositor; ovipositor (fully exerted) slightly longer than head and mesosoma combined; sheaths narrower, shorter, and curled. Color: Body mostly black, except scape, pedicel, apical flagellomere, mandible, palpi, and metasomal sclerites very dark reddish brown; flagellomeres 6–8, tarsi apically, ovipositor, and sheaths much lighter yellowish brown; eye and ocelli silvery white; metasomal membranes laterally and ventrally white; forewing

with stigma nearly black; second subdiscal cell of forewing with a deeply infumate, very distinct, darkly pigmented patch.

Variation.—Single paratype female as in holotype except body length 5.6 mm; fore wing length 3.2 mm; vein RS+Ma absent basally but present apically as a short branch (only slightly shorter than vein r).

Diagnosis.—This species can be distinguished from *Betelgeuse aztecus* by the antenna with only 9 flagellomeres, forewing with the stigma nearly black, and second subdiscal cell of forewing with darkly pigmented patch. *Betelgeuse piceus* is more similar to *Betelgeuse variabilis*, NEW SPECIES but can be distinguished by its entirely black head and mesosoma, and by cross-vein 1cu-a of the fore wing, which is strongly angled posteriorly towards wing base.

Distribution.—Known only from the type-locality in Chiapas, Mexico.

Remarks.—The arrangement of antennal placodes in five distinct ranks on flagellomere 9 (Fig. 6) indicates that this elongate apical flagellomere is probably formed from the fusion of five flagellomeres. Therefore, the presence of 13 flagellomeres (as in *Betelgeuse aztecus*) is probably the primitive condition for the genus. The elongated 9th flagellomere is interpreted here as a synapomorphy indicating the close phylogenetic relationship of the two new species described in this paper.

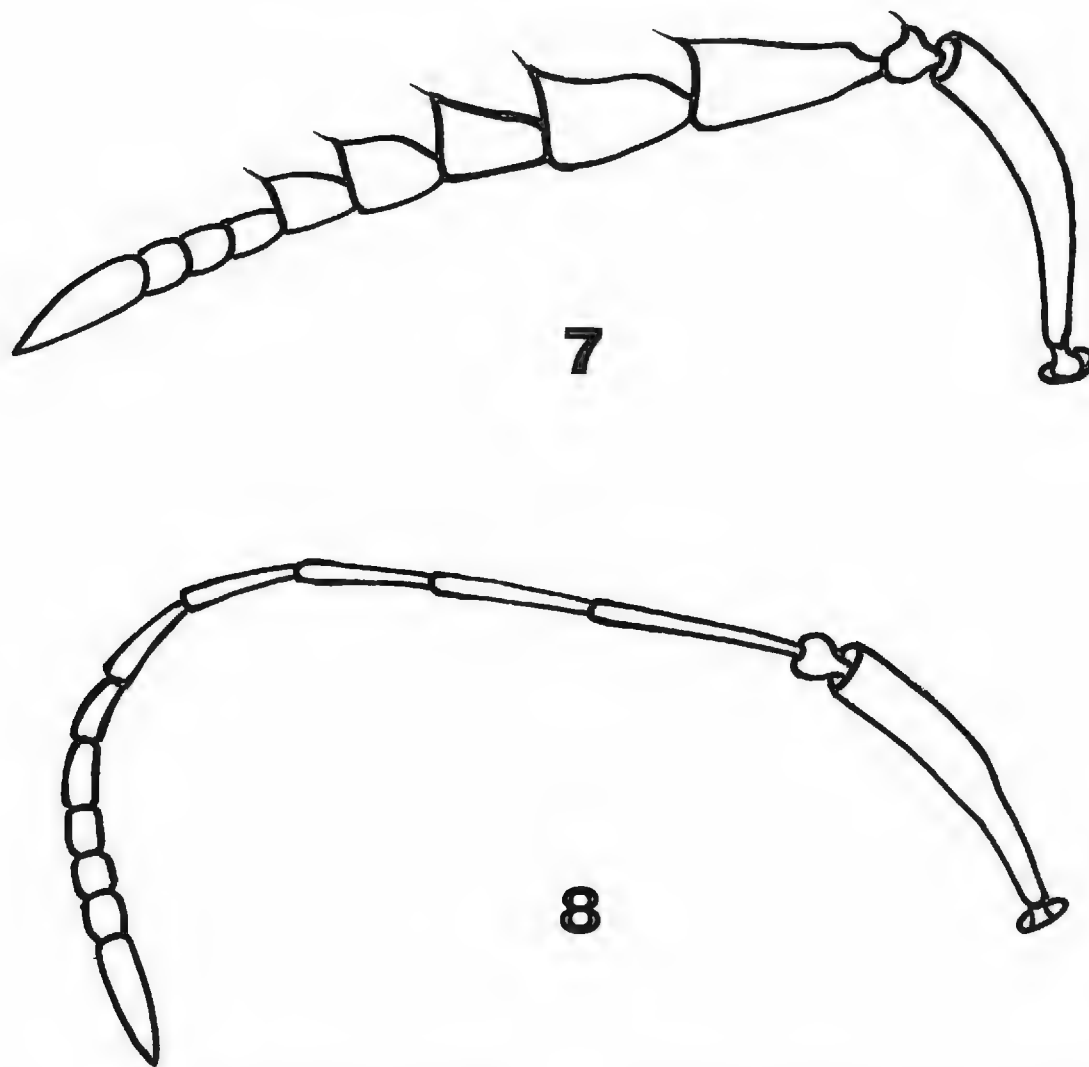
Etymology.—The species epithet *piceus* is derived from the Latin for “pitch-black,” in reference to the predominant black body color of this species.

BETELGEUSE VARIABILIS SHAW, NEW SPECIES

(Figs. 7 and 8, 10–13)

Types.—Holotype, female; data: MEXICO. Hgo. (= Hidalgo), Hwy. 105 2.7 mi N. Tlanchinol, 5000', 15 June 1983, C. W. & L. O'Brien & G. B. Marshall [deposited at California Academy of Sciences, San Francisco]. Paratypes: 1 male, same data as holotype; 1 male, same data as holotype except collected 2 August 1982, C. W. & L. O'Brien & G. Wibner, collectors [deposited at California Academy of Sciences, San Francisco and University of Wyoming Insect Museum, Laramie].

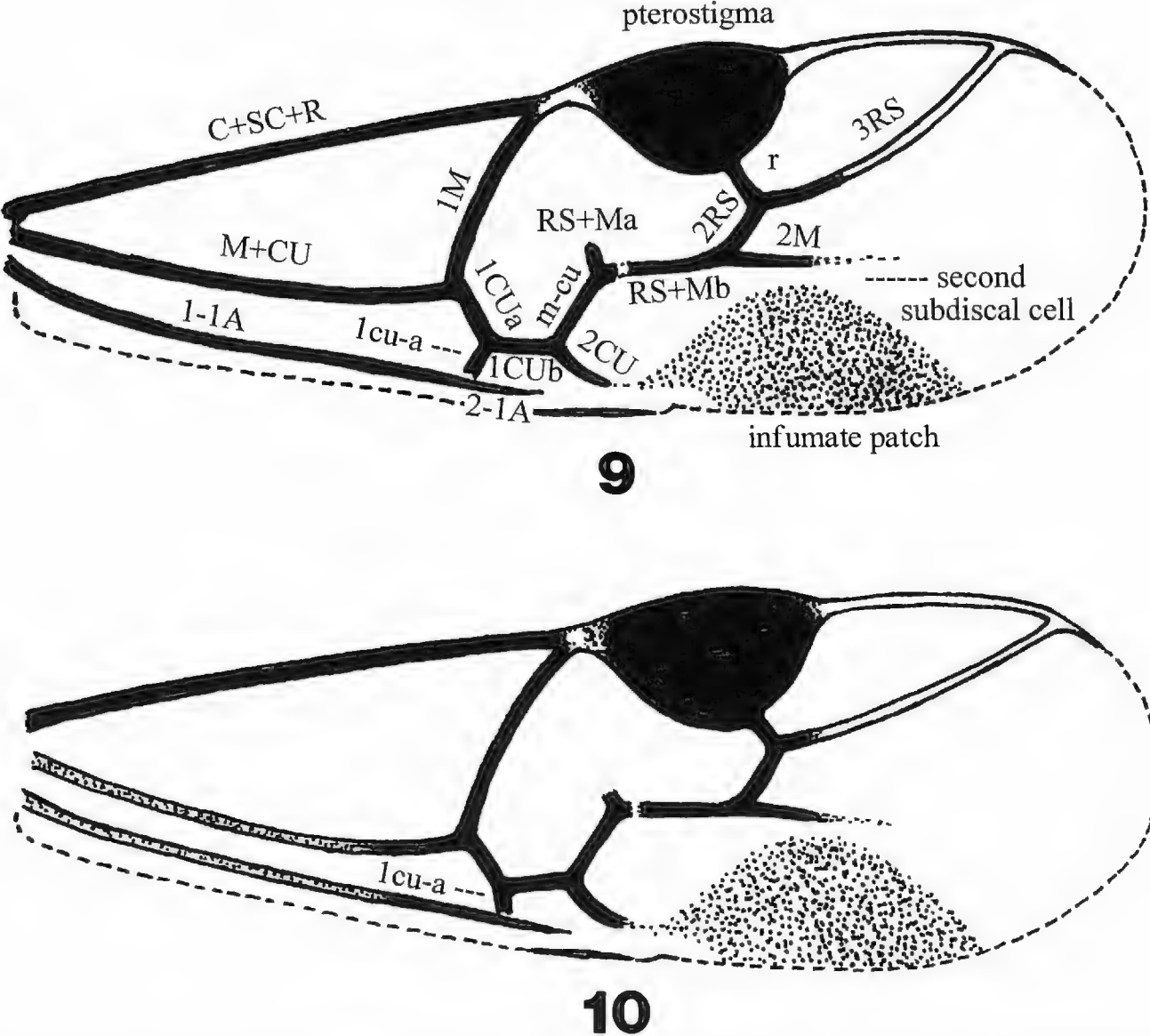
Description of Holotype Female.—Body length 4.5 mm; forewing length 3.6 mm. Head transverse, in dorsal view 2.6× broader than long; surface sculpture coarsely and evenly rugose; eye elongate oval, not bulging anteriorly beyond face; eyes in anterior view distinctly converging ventrally; shortest inter-ocular distance 1.4× clypeus width; eye apparently glabrous but with scattered minute setae; median frontal carina absent, rugose facial sculpture interrupted medially by a vertical groove; inter-antennal distance 2.5× socket width; scrobes very slightly protuberant; scape elongate, gradually curved, gradually wider apically, somewhat flattened dorso-ventrally; scape length 5.0× width at apex; pedicel somewhat globose, except dorsally with a short serration; flagellum 9-segmented, considerably shorter than body length; flagellomeres 1–4 longer than wide, F5 about as long as wide, F1–F4 of similar width, F5 slightly less wide, F1–F5 somewhat flattened, forming serrations antero-laterally, each serration terminating apically in a point with a single large seta; F1 1.8× longer than apical width; F2–F5 each relatively shorter than preceding flagellomere; F6–F8 each compact, about as long as wide; apical flagellomere (F9) 3.8× longer than wide, apically pointed; ocellar triangle small, distance between lateral ocellus and compound eye 2.9× distance between lateral ocelli; occipital carina complete dorsally and somewhat crenulate, ventrally absent and not meeting hypostomal carina; malar space short, about 1/6 eye height; malar suture absent; facial setae minute, not obscuring face; lower clypeal margin truncate; mandibles very sharply pointed; maxillary palpus 5-segmented; labial palpus 2-segmented. Mesosoma with surface sculpture entirely coarsely rugose to rugo-punctate; notaulus and sternaulus indistinct from general rugose sculpture; scutellar furrow 14-foveate; anterior margin of scutellar furrow weakly carinate; scutellum large, triangular, and projecting posteriorly as



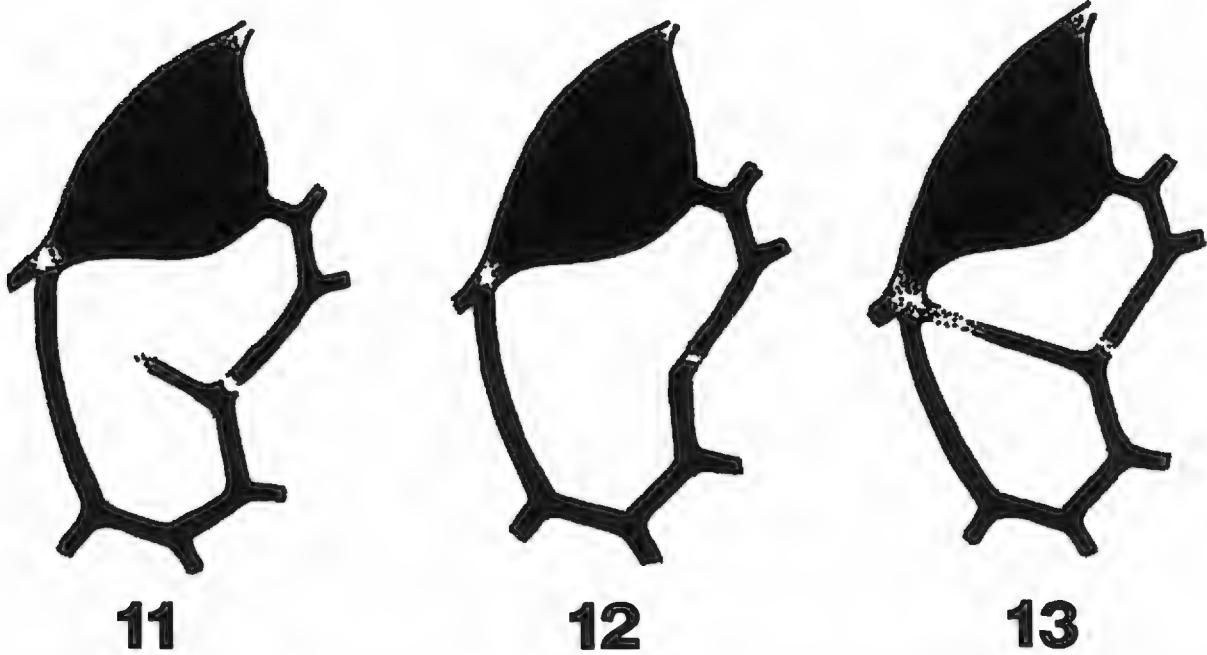
Figures 7–8, antenna of *Betelgeuse varibilis*, NEW SPECIES, anterior view. Figure 7. Female. Figure 8. Male.

a distinct conical point; propodeum with deep postero-median impression, as deep as basal width of petiole (metasomal tergum 1); postero-lateral corners of propodeum developed as lateral tubercles; petiolar notch short, not extending past metacoxal cavity; hind coxa rugose, remainder of leg coarsely granular; metafemur length $4.5\times$ maximum width; tarsal claw simple. Fore wing with pterostigma large, nearly semi-circular; forewing vein 1M only very slightly curved, nearly straight; vein RS+Ma absent basally but present apically as short branch about $\frac{1}{4}$ to $\frac{1}{2}$ as long as vein r (short branch of vein RS+Ma longer in left wing than in right wing); vein RS+Mb long and slightly curved; vein 3RS entirely tubular and distinct, reaching wing margin well before wing apex; marginal cell about equal to pterostigma length; vein r-m absent; vein M+CU slightly curved at middle; tubular portion of vein 2M about equal in length to vein r; vein 1CUa angled posteriorly at 110° relative to vein M+CU; vein 2CU slightly longer than m-cu, curved apically; vein 1cu-a postfurcal by distance $1.5\times$ greater than its length, vertical or angled slightly away from wing base; vein 2-1A short and straight, about equal in length to 1Cub. Hind wing with 3 hamuli; vein RS indicated by infumate line nearly reaching wing tip; vein 2M spectral; vein cu-a curved, meeting vein 1A posteriorly in a tubular joint, without obvious bulla or wing fold. Metasoma with petiole not fused ventrally, apex $3.5\times$ broader than base, about $0.75\times$ as long as metasoma beyond petiole (excluding ovipositor); tergum 1 weakly longitudinally rugose over basal $\frac{3}{4}$, smooth over apical $\frac{1}{4}$; glymma absent; dorsope absent; petiolar spiracles just beyond middle of petiole, not prominent; syntergum 2+3 smooth and highly polished, about $\frac{3}{4}$ as long as petiole; lateral fold of syntergum 2+3 present; suture between terga 2+3 present laterally; terga 4–8 exposed beyond syntergum 2+3, all smooth and highly polished; tergum 8 short and strongly compressed to form a vertical slit above ovipositor; ovipositor (fully exerted) slightly longer than head and mesosoma combined; sheaths narrower, shorter. Color: Body mostly dark reddish brown, except scape, pedicel, mandible, fore and middle coxae, ovipositor, and sheaths lighter yellowish brown; flagellomeres 6–8 light yellowish white; eye and ocelli silvery white; metasomal membranes laterally and ventrally white; forewing with stigma dark brown; second subdiscal cell of forewing with a deeply infumate, very distinct, darkly pigmented patch.

Variation, Paratype Males.—Aside from primary sexual differences, similar to female except body



Figures 9–10, fore wing of *Betelgeuse* females. Figure 9. *Betelgeuse piceus*, NEW SPECIES. Figure 10. *Betelgeuse varibilis*, NEW SPECIES.



Figures 11–13, medial area of fore wing of male *Betelgeuse varibilis*, NEW SPECIES showing variation of vein RS+Ma, first submarginal, and first discal cell. Figure 11. Right wing of paratype (August 2) with vein RS+Ma partly present. Figure 12. Left wing of paratype (June 15) with vein RS+Ma absent. Figure 13. Right wing of paratype (June 15) with vein RS+Ma entirely present.

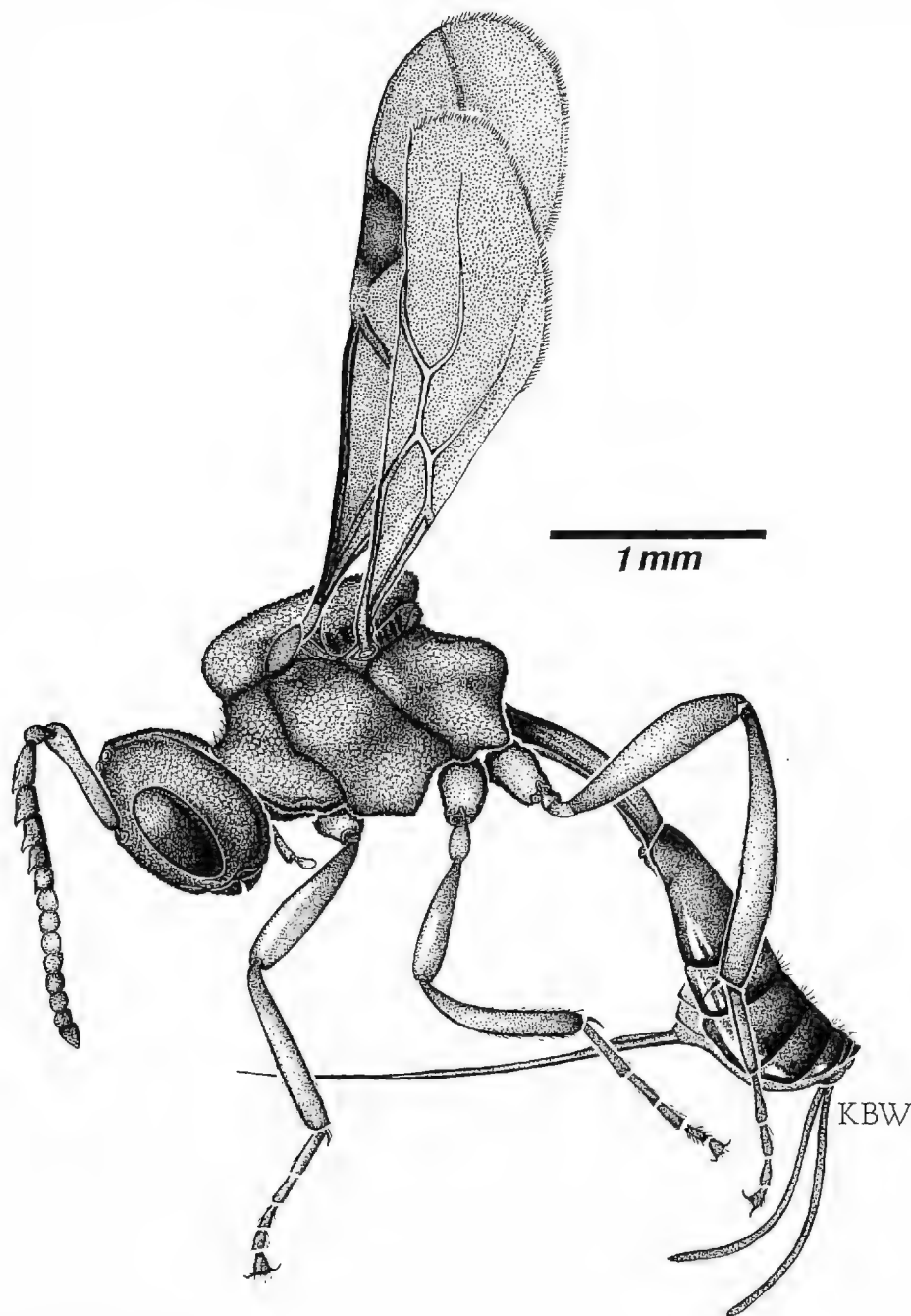


Figure 14. Habitus of *Betelgeuse aztecus* Shaw.

somewhat larger and more robust; body length 5.4–6.0 mm; fore wing length 4.1–4.2 mm; head not as broad and narrow as in female, in dorsal view 2.3–2.4× broader than long; eyes smaller and face wider than in female, shortest inter-ocular distance 2.2× clypeus width; rugose facial sculpture not interrupted medially by a vertical groove; inter-antennal distance wider than in female, 3.0× socket width; antenna longer and more slender than in female, not serrate (Fig. 8); scape cylindrical in cross-section, not flattened dorso-ventrally as in female; scape length 4.7× width at apex; pedicel globose; flagellum slender, flagellomeres 6–11 shorter and wider than F1–5 giving the flagellum a slightly clavate appearance; F1 9.3× longer than wide; F2 6.7× longer than wide; F3 6.0× longer than wide; F4 5.3× longer than wide; F5 4.3× longer than wide; F6–7 each 2.0× longer than wide; F8–10 each 1.4× longer than wide; F11 (apical flagellomere) 3.5× longer than wide; distance between lateral ocellus and compound eye much wider than in female, equal to 3.5× distance between lateral ocelli; malar space very broad, about $\frac{3}{4}$ eye height; scutellar furrow 10–12-foveate; mesonotum with antero-submedial areas and postero-lateral areas smoother and slightly depressed, as compared with female; metafemur length 4.8× maximum width; forewing vein 1M gradually and evenly curved; vein RS+Ma varying from completely present, to partly present as a short branch about equal in length to vein r, to completely absent (one specimen has vein RS+Ma absent in the left wing but completely present in the right wing); hindwing vein RS absent basally but apically indicated by infumate line nearly reaching wing tip; vein 2M indicated by infumation nearly reaching lower wing margin; petiolar spiracles situated more posteriorly than in female, about $\frac{2}{3}$ distance from base of petiole; petiolar sculpture more coarse than in female, extending further posteriorly; metasoma beyond petiole shorter

and broader than in female; tergum 8 not compressed to form a vertical slit; genitalia short and barely exposed; parameres tapering to rounded, setose tips.

Diagnosis.—*Betelgeuse variabilis*, NEW SPECIES can be distinguished from *Betelgeuse aztecus* by the antenna with only 9 flagellomeres and second subdiscal cell of forewing with darkly pigmented patch. *Betelgeuse variabilis* is similar to *Betelgeuse piceus* NEW SPECIES but can be distinguished by its reddish brown head and mesosoma, and by the cross-vein 1cu-a of the fore wing, which is vertical or slightly angled away from the wing base (Fig. 10).

Distribution.—Known only from the type-locality in Hidalgo, Mexico.

Remarks.—This description represents the first record of males for this genus. Previously all genera in the tribe Dinocampini were thought to reproduce via thelytokous parthenogenesis, with males being absent or extremely rare. Since this species is only known from three specimens, it is uncertain if this record of males is a rare occurrence (as in other dinocampines) or if males are common in this species. The males differ most notably from females by the antennal flagellum being slender and gradually wider apically (Fig. 8), not serrate as in females of this genus. However, the very coarse sculpture of the mesosoma and propodeum with large tubercles remain diagnostic for the genus, regardless of sex.

The range of variation in the form of fore wing vein RS+Ma in this species is quite remarkable, and merits special discussion. In most Braconidae this vein is either present or absent, and its presence or absence is often used as a diagnostic character for genera. There are few published cases in the family Braconidae where a single species exhibits so much variation for wing venation (Konig 1972), and it's remarkable that only three specimens should show so much variation. In the female holotype vein RS+Ma is present as an apical short branch (Fig. 10), but this varies in length between the left and right wing of the same specimen. The male paratype dated 2 August 1982 is presumably "normal" in that the wings are symmetrical, with both wings having an apical branch of vein RS+Ma that extends half-way across the combined first submarginal and discal cells (Fig. 11). The male paratype dated 15 June 1983 is presumably "abnormal" in that the wings are asymmetrical: vein RS+Ma is entirely absent from the left wing (thus the first submarginal and discal cells are combined) (Fig. 12), while it is more or less entirely present in the right wing (thus the first submarginal and discal cells are clearly separated) (Fig. 13). In the right wing of this specimen the basal $\frac{1}{3}$ of vein RS+Ma is not tubular, but it is clearly indicated by very dark pigmentation. The apical $\frac{2}{3}$ of the vein is clearly tubular and strongly indicated.

In my previous paper (Shaw 1988) the significance of the absence of this vein in *Betelgeuse aztecus* was discussed (under the older Muesebeckian system the same vein was termed the "first segment of the cubitus"). Since other genera of the tribe Dinocampini (e.g., *Dinocampus*, *Ropalophorus*, *Centistina*) have this vein present, its absence in *Betelgeuse* was regarded as a convergence with euphorine section 3 tribes (which mostly lack this vein). Nevertheless, the placement of *Betelgeuse* in the tribe Dinocampini is clearly supported by the elongated scape and labial palpus reduced to 2 segments. The present discovery that two new species of *Betelgeuse* have the vein at least partly present (and that it is a highly plastic character) lends further support to the interpretation of its total loss in some *Betelgeuse* species as an evolutionary convergence.

Etymology.—The species epithet *variabilis* is derived from the Latin for “changeable,” in reference to the extreme variation of fore wing vein RS+Ma exhibited by this species.

ACKNOWLEDGMENTS

Thanks are given to Michael Sharkey (University of Kentucky, formerly Canadian National Collection, Ottawa) and to Robert Zuparko (California Academy of Sciences, San Francisco) for initially recognizing these specimens and calling them to my attention for study. Kathleen M. Horton, Managing Editor of *Psyche*, kindly granted permission to reprint the beautiful habitus illustration done by Kathy Brown-Wing, which was first published in my 1988 paper. Teresa Williams (Western Research Institute), assisted with the environmental scanning electron microscope.

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REVIEW OF THE GENUS *HESPEROBAENUS* LECONTE (COLEOPTERA: MONOTOMIDAE) OF AMERICA, NORTH OF MEXICO

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Abstract.—The genus *Hesperobaenus* LeConte in North America, north of Mexico, is reviewed. One new species is described, *H. constricticollis*, NEW SPECIES (type locality: Sabal Palm Grove Sanctuary, near Brownsville, Texas) and a new combination, *H. unicolor* (Casey), NEW COMBINATION is proposed. *Hesperobaenus arizonicus* Casey, NEW SYNONYM, is placed for the first time in synonymy with *H. abbreviatus* (Motschulsky). A key is provided for the discrimination of the species along with distributional maps and illustrations of the most important character states.

Key Words.—Insecta, Coleoptera, Monotomidae, *Hesperobaenus*, new species, new combination, North America.

The genus *Hesperobaenus* was described by John L. LeConte in 1861 for two species, *Monotoma rufipennis* LeConte of North America, now a junior synonym of *Hesperobaenus abbreviatus* (Motschulsky), and *Rhizophagus capito* Fairmaire of Honolulu, Hawaii. Since then, only a few species have been added to the genus, all from North America and Central America. The genus has never been revised and species discrimination is very difficult with the existing literature.

The purpose of this work is to provide a taxonomic review of the species of *Hesperobaenus* occurring in Canada and the United States.

MATERIALS AND METHODS

This review is based on the study of about 1600 specimens of *Hesperobaenus*. The material was borrowed from the following institutions referred to in the text by their acronyms. Names of curators follow the institutional addresses.

- AMNH: Department of Entomology, American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024, U.S.A. Lee H. Herman.
- BMNH: The Natural History Museum, Cromwell Road, London SW7 5BD, England. Malcolm Kerley.
- CAS: Department of Entomology, California Academy of Sciences, Golden Gate Park, San Francisco, California 94118, U.S.A. David H. Kavanaugh.
- CDAE: California State Collection of Arthropods, Department of Food and Agriculture, 1220 N Street, Sacramento, California 95814, U.S.A. Fred G. Andrews.
- CMNH: The Carnegie Museum of Natural History, 4400 Forbes Avenue, Pittsburgh, Pennsylvania 15213-4080, U.S.A. Robert L. Davidson.
- CNC: Canadian National Collection of Insects, Agriculture and Agri-Food Canada, Ottawa, Ontario K1A 0C6.

- CUIC: Department of Entomology, Cornell University, Ithaca, New York 14850, U.S.A. James K. Liebherr.
- FMNH: Field Museum of Natural History, Roosevelt Road at Lake Shore Drive, Chicago, Illinois 60605, U.S.A. Alfred F. Newton, Jr.
- FSCA: Florida State Collection of Arthropods, Florida Department of Agriculture and Consumer Services, P.O. Box 147100, Gainesville, Florida 32614, U.S.A. Michael C. Thomas.
- INHS: Section of faunistic surveys and insect identification, Illinois Natural History Survey, 607 East Peabody Drive, Champaign, Illinois 61820, U.S.A. Kathryn C. McGiffen.
- LSUC: Louisiana State University Insect Collection, Department of Entomology, Louisiana State University, Baton Rouge, Louisiana 70803, U.S.A. Vicky L. Moseley.
- MCZ: Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts 02138, U.S.A. David G. Furth.
- NHDE: Entomological Museum, Department of Zoology, University of New Hampshire, Durham, New Hampshire 03824, U.S.A. Donald S. Chandler.
- OSUC: Department of Entomology, Ohio State University, 1735 Neil Avenue, Columbus, Ohio 43210, U.S.A. Charles A. Triplehorn.
- TAMU: Department of Entomology, Texas A&M University, College Station, Texas 77843, U.S.A. Edward G. Riley.
- USNM: National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20560, U.S.A. Gloria N. House.

The following measurements were made on some specimens using an ocular micrometer in a stereoscopic microscope at 80 $\times$: maximum width of head, including eyes (WH); maximum width of pronotum (WP); length of pronotum along midline (LP); length of elytra from posterior extremity of scutellum to tip of right elytron (LE).

GENUS *HESPEROBAENUS* LeCONTE, 1861

Hesperobaenus LeConte 1861: 86. Type species: *Monotoma rufipennis* LeConte, 1858 (= *Rhyzophagus abbreviatus* Motschulsky, 1845), PRESENT DESIGNATION [the designation of *Hesperobaenus abbreviatus* by Sharp (1900: 565) is invalid since the species was not originally included in the genus]. Horn (1879a: 262); Blatchley (1910: 667); Casey (1916: 91); Arnett (1962: 768); Sen Gupta (1988: 17, 44); Downie and Arnett (1996: 985, 988).

Recognition.—The following character states distinguish members of *Hesperobaenus* from those of other genera of Nearctic Monotomidae. Head without antennal grooves. Antenna with 3-segmented club (seemingly 2-segmented). Pronotal disc with impunctate median zone. Elytral disc with setigerous punctures arranged in longitudinal rows; inflexed part of elytron with 4–5 rows of punctures (punctures of medial rows are more or less confused in most species). Fore coxae rounded. Sen Gupta (1988) provided a detailed description of the genus.

Habitat.—Very little is known about the habitat requirements of the species of *Hesperobaenus*. Label information attached to specimens studied suggest that they are associated with yucca and sotol plants (family Liliaceae) or are found under

the bark of dead trees. The species are probably fungus feeders. Lawrence (1991) reported that *Hesperobaenus* species have been taken in fruiting bodies of *Hypoxylon* and *Daldinia* (Ascomycetes: Xylariaceae).

Discussion.—Beside the species treated in the present work, four other names are associated with the genus *Hesperobaenus* (see Hetschko 1930): *capito* Fairmaire, 1850 (originally described as a member of *Rhizophagus*) reported from Tahiti and the Hawaiian Islands; *humeralis* Reitter, 1873 listed by Hetschko (1930) as a junior synonym of *capito*; *lineellis* Reitter, 1873 (originally described as a member of *Europs*) reported with doubt from North America; and *stipes* Sharp, 1900 reported from Guatemala. According to Sharp (1900: 565), *capito* belongs to the genus *Europs*. I have studied the type specimen of *stipes* (BMNH); it differs from other *Hesperobaenus* species in having only three rows of setigerous punctures on the inflexed part of the elytron. Its generic position remains uncertain but I doubt that it belongs to the genus *Hesperobaenus*.

KEY TO NEARCTIC SPECIES OF *HESPEROBAENUS*

- 1. Elytral intervals 3 and 5 with setigerous punctures at least over most of anterior half. Male last visible sternite with large, oval and shallow median depression 2
- Elytral intervals 3 and 5 without setigerous punctures or at most with 1–4 punctures at base. Male last visible sternite without depression 3
- 2. Scutellum without setigerous punctures. Eyes convex, temples at least $\frac{1}{3}$ longitudinal diameter of eyes (Fig. 2) *H. alternatus* Schaeffer
- Scutellum with 1–4 short setigerous punctures. Eyes less convex, temples distinctly shorter, less than $\frac{1}{3}$ longitudinal diameter of eyes (Fig. 3) ...
..... *H. unicolor* (Casey)
- 3. Metacoxal bead, on first visible abdominal sternite, triangularly produced, with or without linear prolongation 4
- Metacoxal bead, on first visible abdominal sternite, not triangularly produced, at most somewhat thickened, without linear prolongation 6
- 4. Scutellum with setigerous punctures. Pronotum elongate (LP/WP = 1.06–1.14). Prosternal apophysis with isodiametric microsculpture
..... *H. fenyesi* Van Dyke
- Scutellum without setigerous punctures. Pronotum transverse to subquadrate (LP/WP = 0.90–1.05). Prosternal apophysis without microsculpture or with microsculpture near apex only 5
- 5. Pronotum subquadrate (LP/WP = 0.96–1.05) with punctures subcontiguous laterally. Temples long, more than half longitudinal diameter of eyes (Fig. 6). Anterior half of elytra distinctly paler than posterior half in most specimens. Anterior angles of pronotum laterally slightly produced in most specimens (Fig. 6) *H. abbreviatus* (Motschulsky)
- Pronotum slightly transverse (LP/WP = 0.90–0.96) with punctures not subcontiguous laterally. Temples shorter, half longitudinal diameter of eyes or less (Fig. 7). Elytra more or less uniformly colored. Anterior angles of pronotum not produced laterally (Fig. 7). .. *H. rufipes* LeConte
- 6. Pronotum only slightly narrowed basally (Fig. 4). Temples long, more than half longitudinal diameter of eyes (Fig. 4) *H. subtestaceus* Reitter

- Pronotum markedly narrowed basally (Fig. 8). Temples shorter, less than half longitudinal diameter of eyes (Fig. 8) *H. constricticollis* n.sp.

HESPEROBAENUS ALTERNATUS SCHAEFFER, 1910

Hesperobaenus alternatus Schaeffer, 1910: 213. Type locality: ARIZONA. Huachuca Mts.

Type Material.—Schaeffer (1910) described *H. alternatus* from an unspecified number of specimens collected in the Huachuca Mountains in Arizona. The USNM contains two specimens of that species, a male and a female, in the general collection, both labelled as “Type”. These syntypes bear the following labels: “Huach Mts. Ariz./TYPE/alternatus Schaeff. [handwritten]/Hesperobaenus alternatus Schaeff. [handwritten]/C. Schaeffer Collection R.11.II.36 [partly handwritten]/Nevermann Collection 1940”.

Description.—Habitus (Fig. 1). Body length: 2.9–3.5 mm. *Coloration*.—Dorsal surface red-brown, disk of elytra slightly paler than pronotum in many specimens. *Microsculpture*.—Prosternal apophysis without microsculpture. *Head*.—Wider in males (WH/WP = 0.97–1.02; $\bar{x}$ = 0.99; n = 10) than in females (WH/WP = 0.90–0.95; $\bar{x}$ = 0.92; n = 10). Eye convex, longitudinal diameter 1.5–1.6 $\times$ length of antennomere I. Temple moderately long, 0.6–0.7 $\times$ longitudinal diameter of eye, rounded posteriorly, not produced (Fig. 2). Antennomere IX about as wide as long, subequal in width to antennomere X. *Prothorax*. Pronotum slightly elongate (LP/WP = .99–1.08; $\bar{x}$ = 1.04; n = 20), with maximal width slightly before apex (Fig. 2); anterior angle rounded, not produced; punctures narrowly spaced laterally but not subcontiguous; disc slightly convex, with narrow median impunctate area. Hypomeron not rugose. *Elytra*.—Proportionally short (LE/LP = 1.73–1.93; $\bar{x}$ = 1.83; n = 20), with short, vague, shallow oblique impression on anterior third near suture in many specimens. Third and fifth intervals with numerous setigerous punctures mostly on anterior two-thirds; scutellum without setigerous punctures. *Abdomen*.—First visible sternite with coxal bead rounded, not triangularly produced. Male last visible sternite with shallow, oval, median depression. *Male Genitalia*.—Aedeagus as in Fig. 9.

Diagnosis.—Distinguished from other species of *Hesperobaenus* by the presence of setigerous punctures on the third and fifth elytral intervals in combination with the absence of setigerous punctures on the scutellum.

Distribution.—This species is known from southeastern Arizona and Texas (Fig. 16). Beside the specimens listed below I have seen seven specimens labelled “Florida: Hillsborough Co. Dover, 11.II.1987, J. Felty palm flowers ex Texas” in Florida State Collection of Arthropods, Gainesville, Florida.

Habitat.—Label data indicate that the species is associated with yucca plants.

Material Examined.—ARIZONA. COCHISE Co.: Chiric[ahua] Mts (20, USNM). Chiricahua Mtns., Rucker Cny. (2, CNC) [at light]. Chiricahua Mtns. near Portal (6, FSCA) [Yucca]. 5 mi W Portal (1, CDAE) [Yucca sp. Lep. frass]. W Stronghold (3, FSCA). Stronghold, Dragoon Mtns. (3, MCZ) [ex leaf axils of Yucca with dead flowers in them]. Huach[ucha] Mts. (2, USNM). SANTA CRUZ Co.: Santa Rita Mts. (19, MCZ, USNM). Santa Rita Mts., Madera Cyn. (5, FSCA) [1—dead Sotol]. TEXAS. BASTROP Co.: Bastrop State Park (1, CNC) [light]. BEXAR Co.: San Antonio (19, CNC). BOWIE Co.: Maud (1, OSUC). CAMERON Co.: county record only (17, USNM) [fallen fruit *Yucca treculeana* Carr.]. Brownsville (8, USNM) [Yucca blossom]. GILLESPIE Co.: Fredericksburg (1, CNC). HUDSPETH Co.: Eagle Flat (1, USNM) [Yucca macrocarpa]. KERR Co.: Kerrville (8, CNC) [Yucca flowers/on yucca]. KLEBERG Co.: Kingsville (3, CUIC). SUTTON Co.: Sonora (3, TAMU). “Sinton, Welder Wildlife Fd.” (1, TAMU).

HESPEROBAENUS UNICOLOR (CASEY), 1916, NEW COMBINATION

Europs unicolor Casey, 1916: 95. Type locality: “TEXAS”.

Type Material.—Casey’s collection in USNM contains a single specimen, a

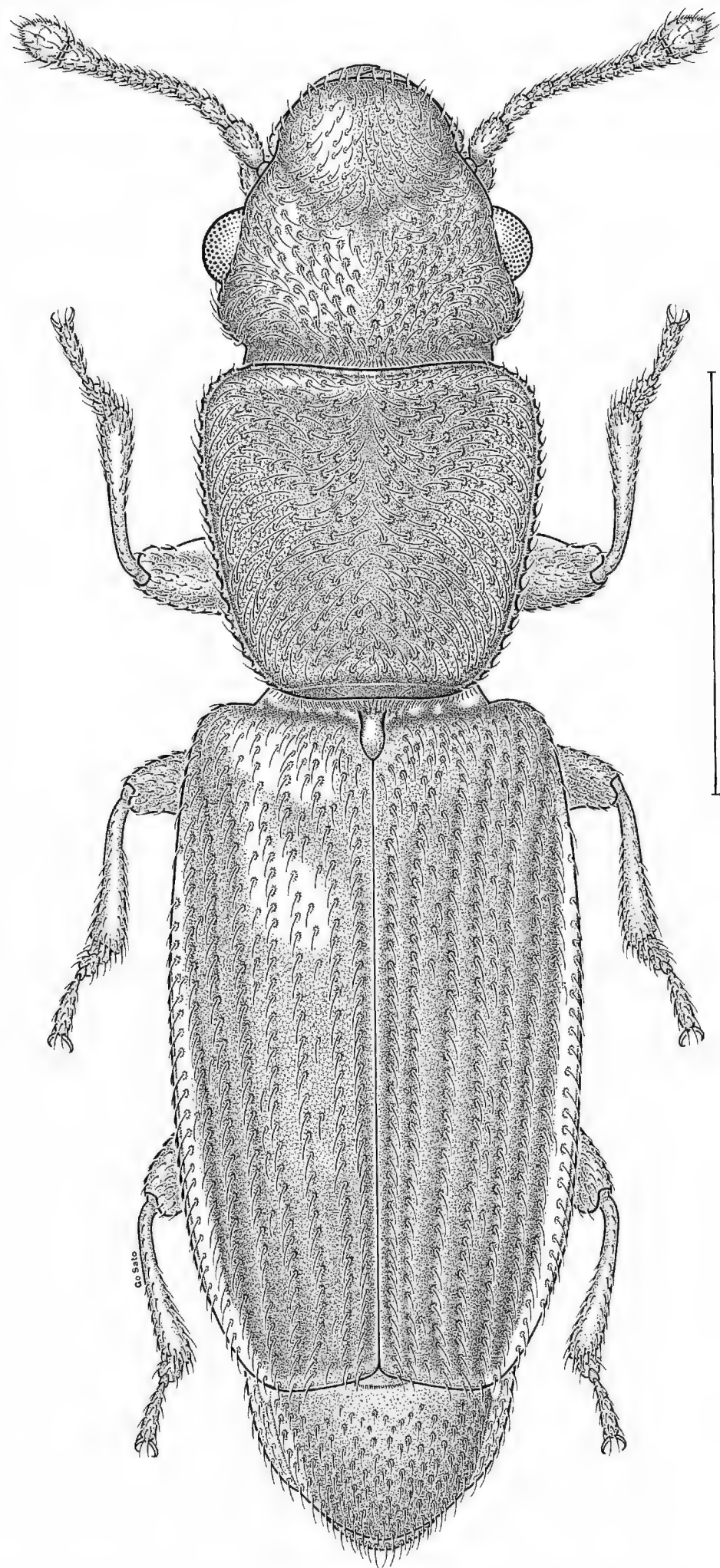
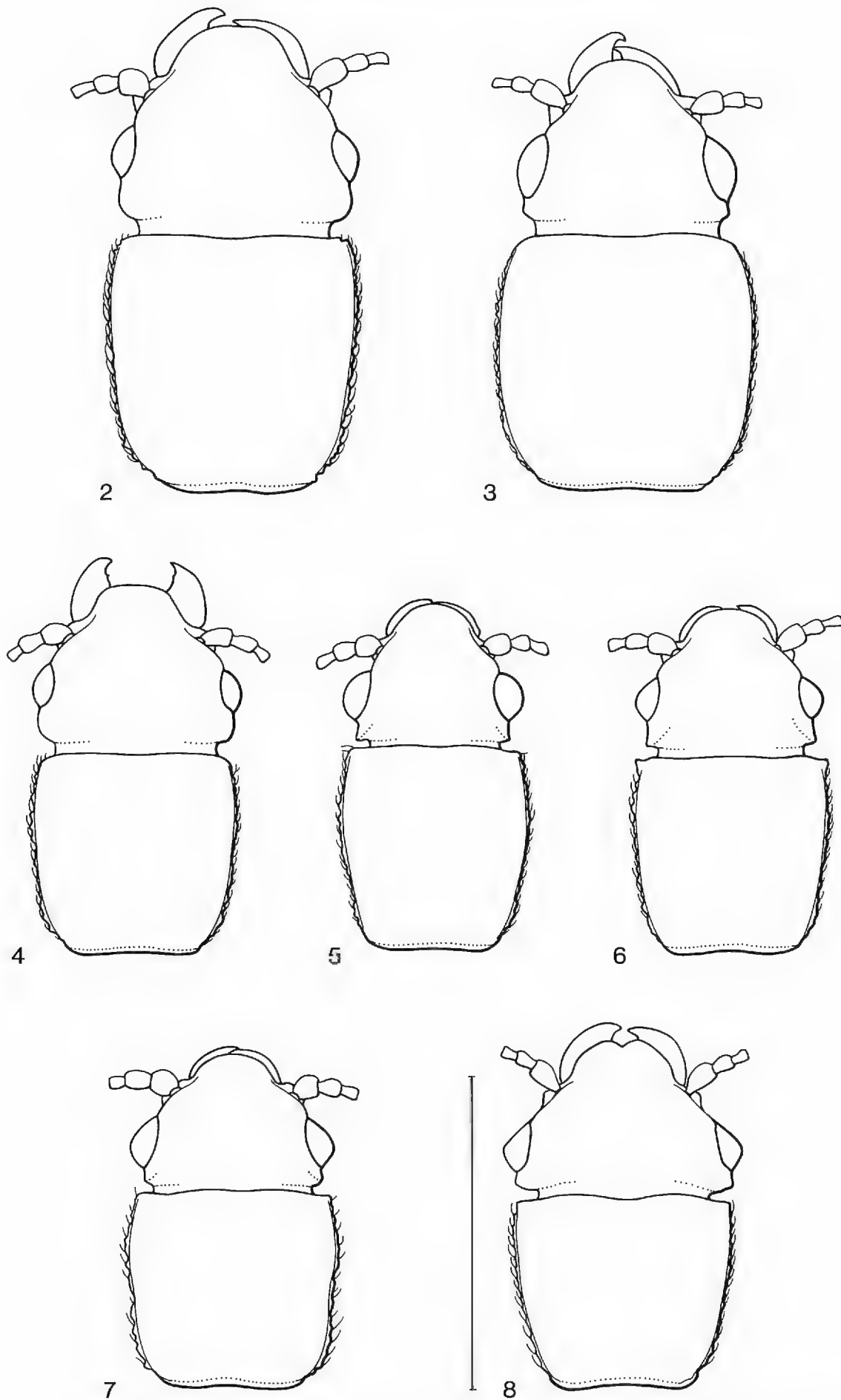


Figure 1. *Hesperobaenus alternatus* Schaeffer (♂), habitus. Scale bar = 1 mm.



Figures 2–8. Head and pronotum, dorsal view. Figure 2. *Hesperobaenus alternatus* Schaeffer (♂); Figure 3. *H. unicolor* Casey (♂). Figure 4. *H. subtestaceus* Reitter (♂). Figure 5. *H. fenyessi* Van Dyke (♀). Figure 6. *H. abbreviatus* Motschulsky (♀). Figure 7. *H. rufipes* LeConte (♀). Figure 8. *H. constricticollis* Bousquet (♂). Scale bar = 1.0 mm.

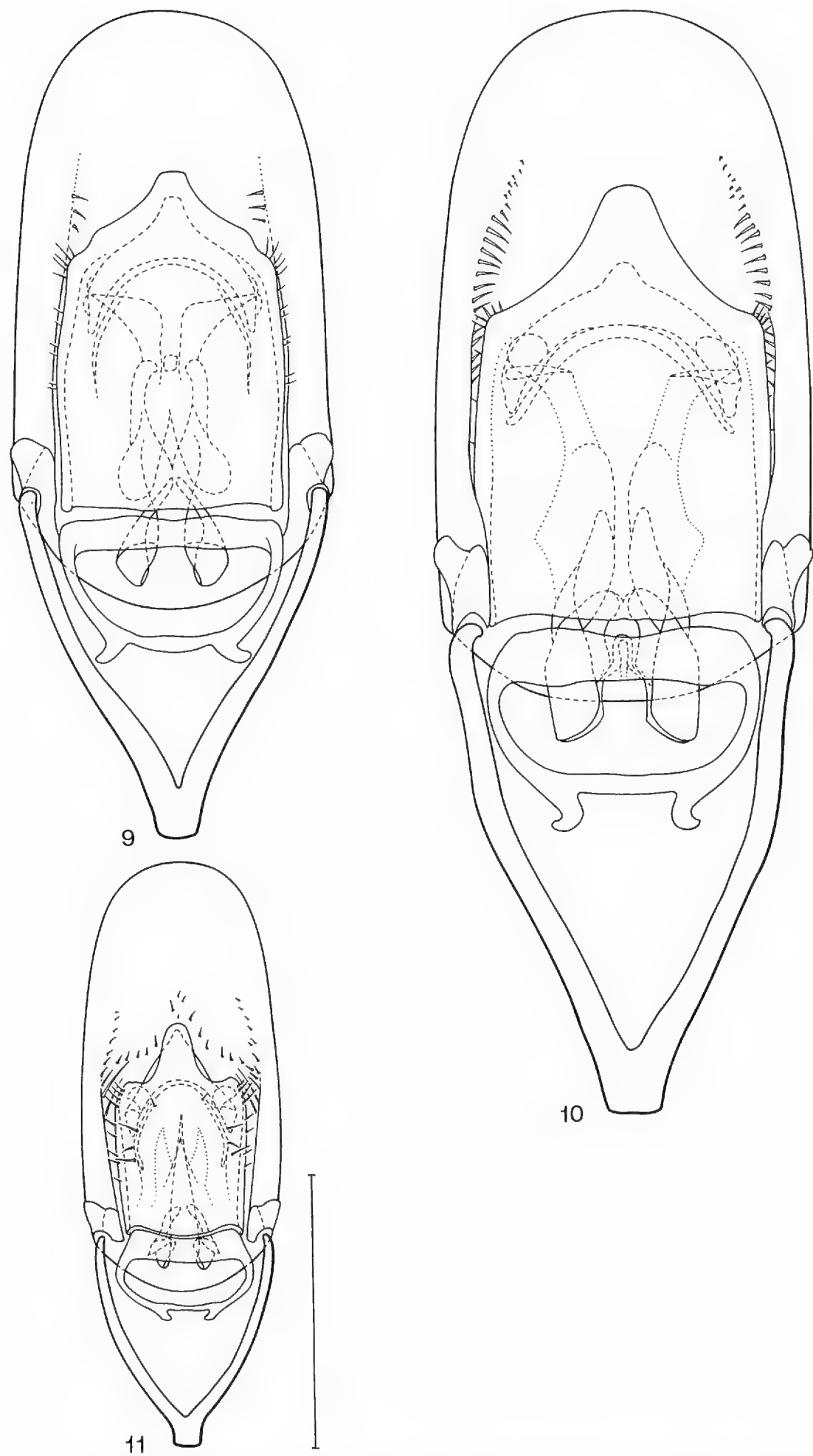


Figure 9–11. Aedeagus. Figure 9. *Hesperobaenus alternatus* Schaeffer. Figure 10. *H. unicolor* Casey. Figure 11. *H. subtestaceus* Reitter. Scale bar = 0.2 mm.

male, labelled: "Tex./Casey bequest 1925/Type USNM 49192/unicolor Csy [handwritten]".

Description.—Same character states as *H. alternatus* except for the following. Body length: 3.0–3.8 mm. *Head*.—Proportionally narrower ($WH/WP = 0.83\text{--}0.91$; $\bar{x} = 0.86$; $n = 10$ in males; $WH/WP = 0.80\text{--}0.84$; $\bar{x} = 0.83$; $n = 10$ in females). Eye longer, longitudinal diameter about twice length of antennomere I; temple shorter, about $0.2\text{--}0.3\times$ longitudinal diameter of eye, and slightly produced posteriorly (Fig. 3). *Prothorax*.—Pronotum with punctuation smaller, punctures more distantly separated; disc flat to slightly depressed; sides more regularly rounded. *Elytra*. Scutellum with 1–4 setigerous punctures. *Male Genitalia*.—Aedeagus as in Fig. 10.

Diagnosis.—Most similar to *H. alternatus* but differs readily by larger eyes, shorter temples and presence of setigerous punctures on the scutellum.

Distribution.—This species is known from southern Arizona, New Mexico and southwestern Texas (Fig. 17).

Habitat.—Label data suggest that this species is associated with sotol plants (*Dasyllirion* sp.).

Discussion.—This species is the adelphotaxon (i.e., sister species) of *H. alternatus*. The presence of setigerous punctures on the third and fifth elytral intervals and the presence of an oval, median depression on the last visible abdominal sternite of the male are synapomorphies for the two species.

Material Examined.—ARIZONA. PIMA Co.: Santa Catalina Mts., Molino Basin, (11, CNC, FSCA) [ex sotol]. Baboquivari Mts. (3, MCZ). SANTA CRUZ Co.: Santa Rita Mts. (4, MCZ, USNM) [2-in dying *Dasyllirion*]. NEW MEXICO. DONA ANA Co.: Organ Mts., Solidad Can. (3, MCZ). LINCOLN Co.: 10 mi. E Carrizozo, Valley of Fire (5, CDAE). TEXAS. BREWSTER Co.: Big Bend Nat. Pk., Green Gulch (18, CNC) [on sotol, *Dasyllirion leiophyllum*]. Alpine (1, USNM). CULBERSON Co.: Guadalupe Mountains Nat. Pk., McKittrick Canyon (1, CNC).

HESPEROBAENUS SUBTESTACEUS REITTER, 1876

Phyconomus subtestaceus Reitter, 1876: 299. Type locality: "MEXICO".

Phyconomus subtestaceus var. *discoideus* Reitter, 1876: 299. Type locality not stated. Synonymy established by Sharp (1900: 565).

Hesperobaenus subtestaceus: Sharp (1900: 565).

Type Material.—Reitter (1876) described *H. subtestaceus* and his variety *discoideus* from an unspecified number of specimens. I have not seen syntypes of these taxa which are probably deposited in the Muséum d'Histoire Naturelle de Paris. However, I have seen a male and female identified by Sharp in BMNH which he compared to the types of *H. subtestaceus* (see Sharp 1900: 565–566).

Description.—Body length: 2.9 mm. *Coloration*.—Dorsal surface red-brown, with area around scutellum and propygidium darker. *Microsculpture*.—Prosternal apophysis without microsculpture. *Head*.—Slightly wider than pronotum ($WH/WP = 1.03$). Eye convex, longitudinal diameter about $1.2\times$ length of antennomere I. Temple moderately long, about $0.7\times$ longitudinal diameter of eye, rounded posteriorly and somewhat bulbous (Fig. 4). Antennomere IX slightly wider than long, about as wide as antennomere X. *Prothorax*.—Pronotum slightly transverse ($LP/WP = 0.97$) with sides slightly convergent in posterior half; anterior angle rounded, not produced (Fig. 4); punctures narrowly spaced laterally, not subcontiguous; disc flat, with moderately wide, median impunctate area. Hypomeron not rugose. *Elytra*.—Moderately long ($LE/LP = 1.92$), with very small, shallow oblique impression on anterior third near suture. Third and fifth intervals with 0–1 setigerous puncture at base; scutellum with 1 setigerous puncture. *Abdomen*.—First visible sternite with coxal bead not triangularly produced, without longitudinal extension. Male last visible sternite without depression. *Male Genitalia*.—Aedeagus as in Fig. 11.

Diagnosis.—Distinguished from other species by features given in the key to species. Superficially most similar to *H. alternatus* but readily differentiated by the absence of setigerous punctures on the third and fifth elytral intervals.

Distribution.—This species is at present known only from southwestern Texas and central Mexico.

Habitat.—No data available.

Material Examined.—TEXAS. 1.8 mi W McDonald Observatory road on Hwy 118, Jeff Davis Co., 9. VIII.1992, W. Godwin & E. Riley (1♂, TAMU). I have also seen 2 specimens from Guanajuato, Mexico (BMNH).

HESPEROBAENUS FENYESI VAN DYKE, 1945

Hesperobaenus fenyesei Van Dyke, 1945: 102. Type locality: CALIFORNIA. Pasadena.

Type Material.—The holotype, a male housed in CAS, is labelled: "Pasadena Cal./Mar./[small yellow round label]/A. Fenyese Collection/Holotype Hesperobaenus fenyesei Van Dyke [handwritten]/California Academy of Sciences Type No. 5436".

Description.—Body length: 2.6–3.1 mm. *Coloration.*—Dorsal surface red-brown, elytra in most specimens slightly paler than forebody. *Microsculpture.*—Prosternal apophysis with isodiametric microsculpture. *Head.*—Not wider in males (WH/WP = 0.96–1.01; $\bar{x}$ = 0.98; n = 8) than in females (WH/WP = 0.93–1.00; $\bar{x}$ = 0.98; n = 10). Eye convex (slightly more than in *H. abbreviatus*), hemispherical, longitudinal diameter about 1.5× length of antennomere I. Temple moderately long, 0.4–0.6× longitudinal diameter of eye, slightly produced posteriorly (Fig. 5). Antennomere IX about as long as wide, slightly narrower than antennomere X. *Prothorax.*—Pronotum elongate (LP/WP = 1.06–1.14; $\bar{x}$ = 1.10; n = 18); anterior angle slightly produced anterolaterally in most specimens (Fig. 5); punctures very narrowly spaced laterally, subcontiguous; disc more or less flat to slightly convex, with narrow, median impunctate area. *Elytra.*—Moderately long (LE/LP = 1.90–2.04; $\bar{x}$ = 1.97; n = 18), with short, vague, shallow oblique impression on anterior third near suture in many specimens. Third and fifth intervals with 0–2 setigerous punctures at base; scutellum with 2–5 setigerous punctures. *Abdomen.*—First visible sternite with coxal bead triangularly produced, with longitudinal extension. Male last visible sternite without depression. *Male Genitalia.*—Aedeagus as in Fig. 12.

Diagnosis.—Distinguished from other *Hesperobaenus* treated by the expanded microsculpture on the prosternal apophysis.

Distribution.—This species is known only from southern California (Fig. 17); it may also occur in Arizona.

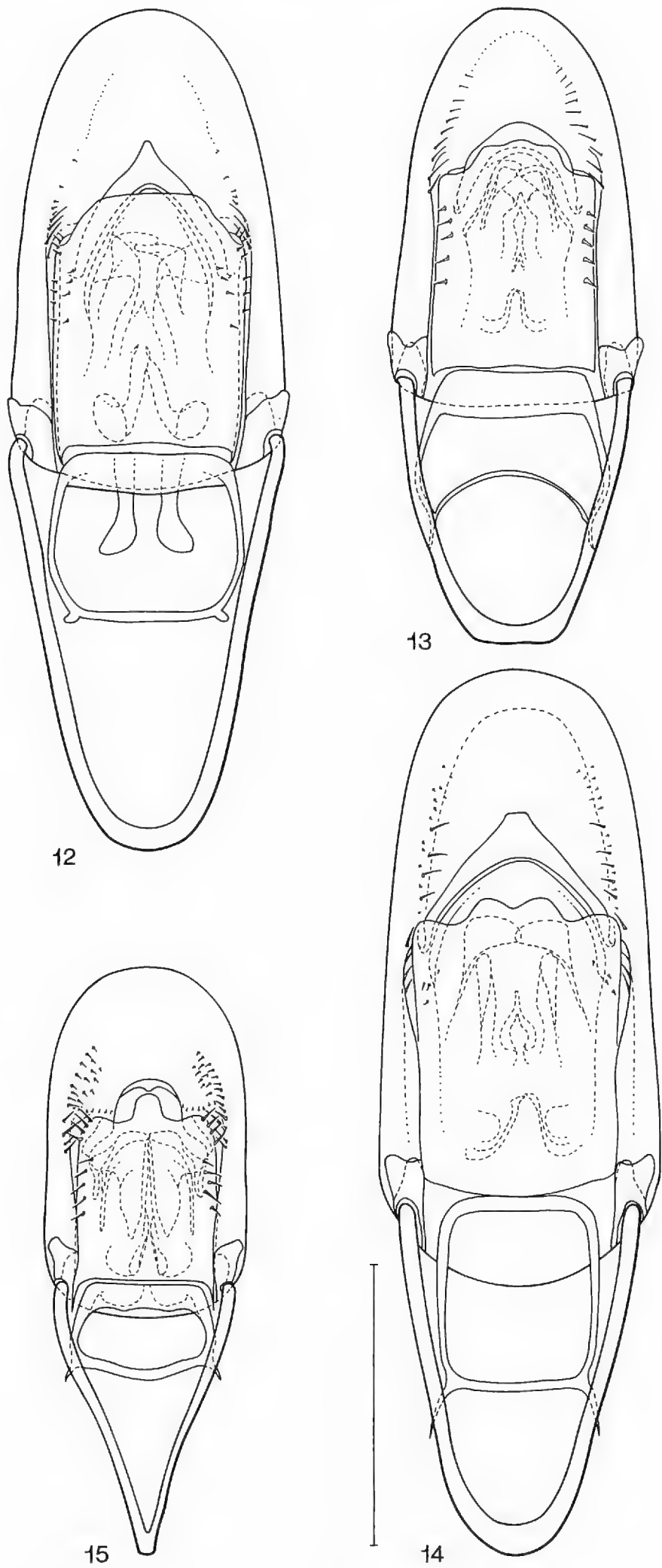
Habitat.—One specimen seen was collected in "decaying yucca".

Material Examined.—ARIZONA. "Ariz" (1, INHS). CALIFORNIA. "Cal." (5, INHS, MCZ, USNM). "S. Cal." (2, CAS, INHS). KERN Co.: 2 mi E Caliente (1, CDAE). Walker Pass (2, CAS). LOS ANGELES Co.: Claremont (1, CDAE). Santa Monica (3, INHS). Pomona (2, MCZ) [decaying yucca]. Sierra Madre (2, CAS). Pasadena (11, CAS, CUC, MCZ, USNM). SAN BENITO Co.: 6 mi E Los Gatos Creek Road (1, CDAE) [antifreeze pit trap]. SAN BERNARDINO Co.: Arrowhead (4, MCZ). SAN DIEGO Co.: Poway (1, CAS). SANTA BARBARA Co.: Carpinteria (1, CAS).

HESPEROBAENUS ABBREVIATUS (MOTSCHULSKY), 1845

Rhyzophagus abbreviatus Motschulsky, 1845: 371. Type locality: «CALIFORNIE».

Monotoma rufipenne LeConte, 1858: 64. Type locality: CALIFORNIA. San Jose. Synonymy established by Horn (1879: 262).



Figures 12–15. Aedeagus. Figure 12. *Hesperobaenus fenyesi* Van Dyke. Figure 13. *H. abbreviatus* Motschulsky. Figure 14. *H. rufipes* LeConte. Figure 15. *H. constricticollis* Bousquet. Scale bar = 0.2 mm.

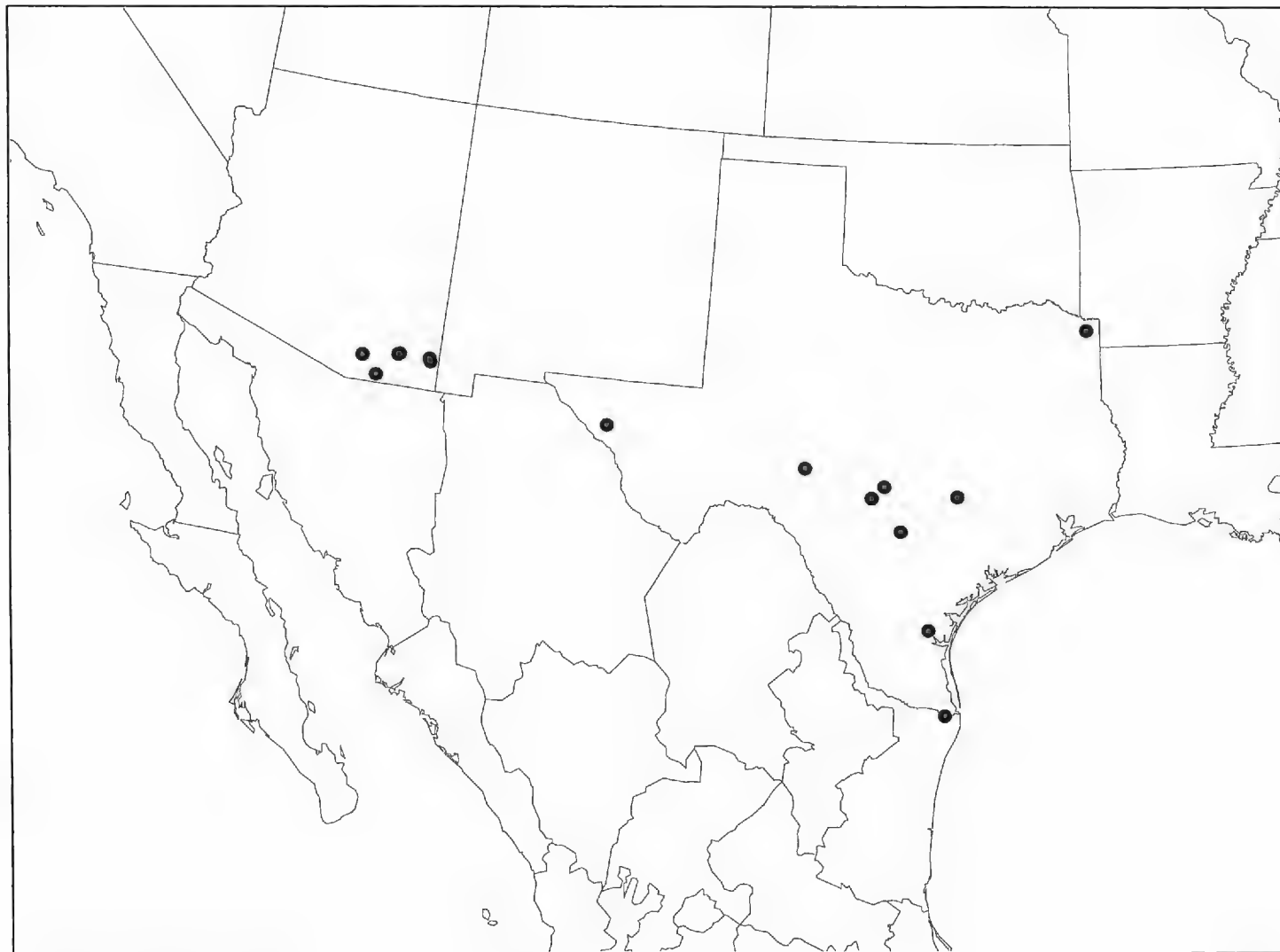


Figure 16. Collection localities for *Hesperobaenus alternatus* Schaeffer.

Rhizophagous corpulentus Reitter, 1873: 35, Type locality: «AMER.». Synonymy established by Horn (1879b: 331)

Hesperobaenus abbreviatus: Horn (1879a: 262); Hatch (1962: 253).

Hesperobaenus arizonicus Casey, 1916: 92. Type locality: «ARIZONA». NEW SYNONYMY.

Type Material.—Motschulsky (1845) described *H. abbreviatus* from an unspecified number of specimens. I have not seen syntypes of this species which are probably housed in the Zoological Museum, Moscow University, Moscow, Russia.

LeConte (1858) described *H. rufipennis* from an unspecified number of specimens. His collection (in MCZ) contains six specimens. The first one, a male, is labelled “Type 7044/*Hesperobaenus rufipennis* Lec. *Monotoma* Lec. S. Jose [handwritten]”. The next three specimens have no labels. The next one is labelled “15 [handwritten]” and the last one “Van.”. Probably only the first one is part of the type series.

Reitter (1873) described *R. corpulentus*, which he credited to “Motsch i. litt.” from an unspecified number of specimens. The location of the syntype(s) is unknown to me.

Casey’s collection in USNM contains one specimen of *H. arizonicus*, a male, labelled: “Ari/Casey bequest 1925/Type USNM 49190/ *arizonicus* Csy. [handwritten]”.

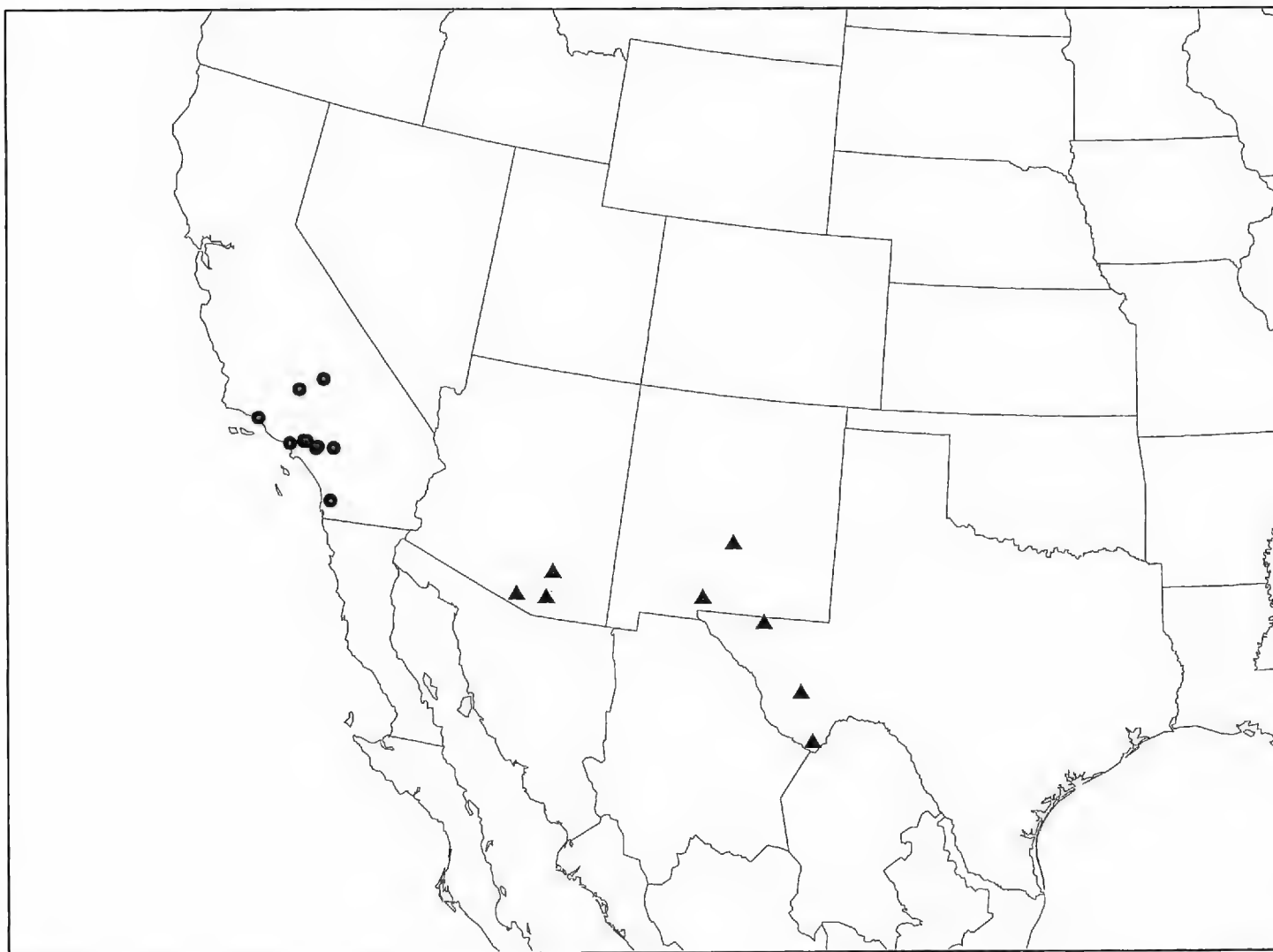


Figure 17. Collection localities for *Hesperobaenus unicolor* Casey (▲) and *H. fenyysi* Van Dyke (●).

Description.—Body length: 2.0–2.8 mm. *Coloration*. Dorsal surface red-brown with basal half of elytra conspicuously paler, yellow to red (a few specimens seen with uniformly pale coloration or with uniformly dark elytra). *Microsculpture*.—Prosternal apophysis with isodiametric microsculpture at apex. *Head*.—Wider in males (WH/WP = 1.00–1.04; $\bar{x}$ = 1.02; n = 10) than in females (WH/WP = 0.89–0.99; $\bar{x}$ = 0.95; n = 10). Eye convex, longitudinal diameter 1.5–1.6 $\times$ length of antennomere I. Temple moderately long, 0.5–0.7 $\times$ longitudinal diameter of eye, and slightly produced posteriorly (Fig. 6). Antennomere IX slightly longer than wide, slightly narrower than antennomere X. *Prothorax*.—Pronotum subquadrate (LP/WP = 0.96–1.05; $\bar{x}$ = 1.01; n = 20), with maximal width at apex or before (apical 4/5); anterior angle slightly produced laterally in most specimens (Fig. 6); punctures very narrowly spaced laterally, subcontiguous; disc slightly convex, with narrow median impunctate area. *Elytra*.—Shorter than in *H. rufipes* (LE/LP = 2.04–2.17; $\bar{x}$ = 2.11; n = 20), with oblique depression on anterior third near suture. Strial punctures finer and shallower than in *H. rufipes*. Third and fifth intervals with 1–4 setigerous punctures at base. Scutellum without setigerous punctures. *Abdomen*.—First visible sternite with coxal bead triangularly produced, with longitudinal extension. Male last visible sternite without median depression. *Male Genitalia*.—Aedeagus as in Fig. 13.

Diagnosis.—Distinguished from other *Hesperobaenus* studied by the bicolored elytra (in most specimens) and the laterally produced anterior angles of the pronotum. Most similar to *H. fenyysi*, especially specimens with uniformly colored elytra, but distinguished by less expanded microsculpture on the prosternal apophysis.

Synonymy.—I have compared the syntype of *H. arizonicus* with several specimens identified as *H. abbreviatus* from California, Washington and British Columbia. I was unable to find any consistent structural differences between the specimens notwithstanding Casey's (1916: 92) statement.

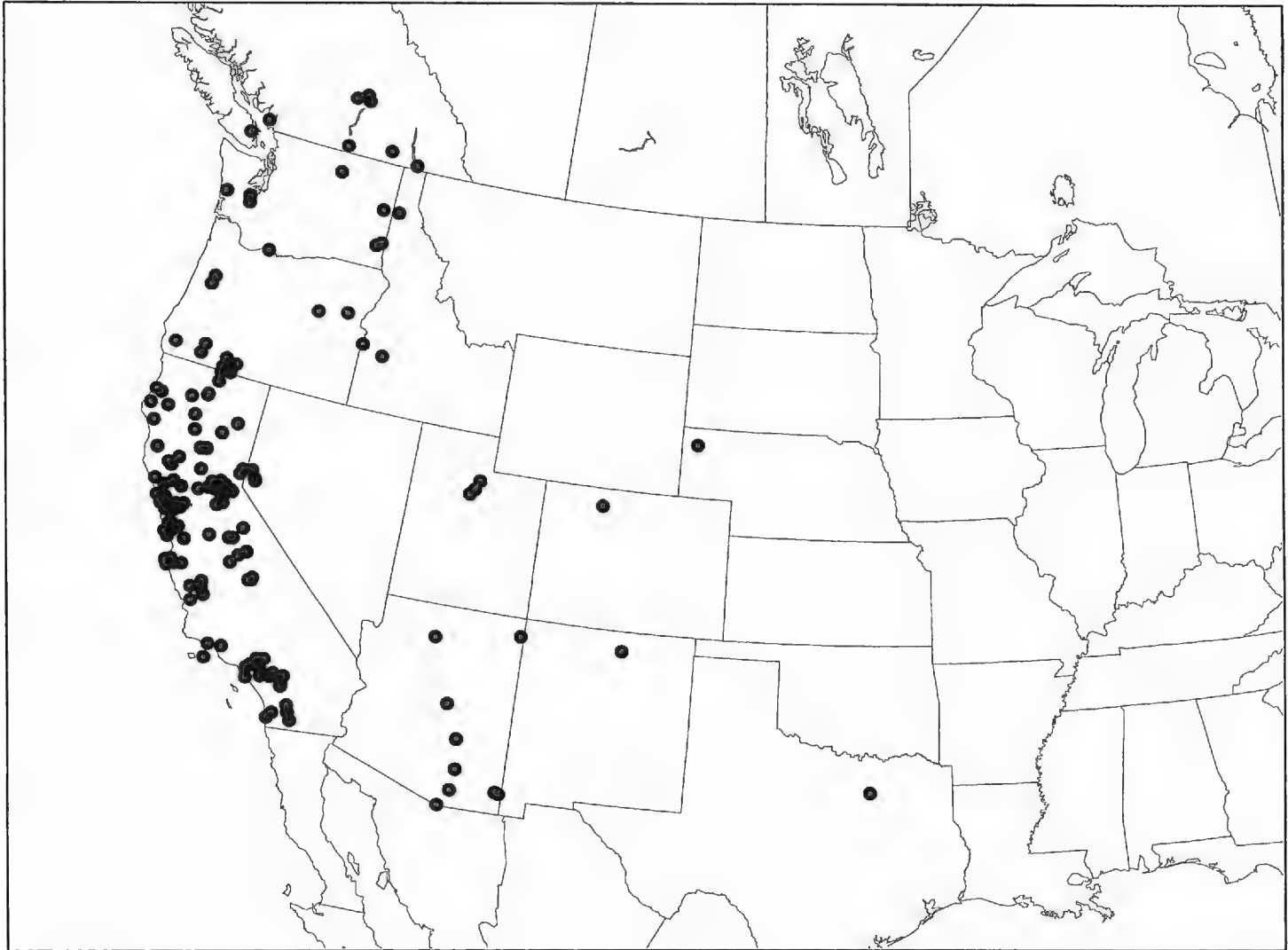


Figure 18. Collection localities for *Hesperobaenus abbreviatus* Motschulsky.

Distribution.—This species ranges from southern British Columbia south to southern California, east to Idaho, Colorado and New Mexico (Fig. 18). The record from Dallas, Texas, is suspect.

Habitat.—Found mainly under the bark of dead trees.

Discussion.—The coloration on the dorsal surface of the body varies for this species. While most specimens (at least 90%) have a red-brown forebody with bicolored elytra, some have the dorsal surface more or less entirely red-brown (mostly specimens from the northern part of the species distribution) and others have the dorsal surface, or the elytra only, entirely pale, flavous (some specimens from the southern part of the species distribution).

Material Examined.—CANADA. BRITISH COLUMBIA. Vancouver (7, CAS, INHS, MCZ) [3—under *Alnus* bark]. Paxton Valley (1, CAS). Creston (9, CNC, CUIC, MCZ, USNM) [4—excordwood]. Oliver (2, CNC). 7 mi N Oliver (1, CNC). Salmon Arm (3, CNC). Enderby (1, CNC). Robson (1, CNC). Duncan (1, CNC). UNITED STATES OF AMERICA. ARIZONA. APACHE Co.: Chuska Mts. (1, MCZ) [under bark of *Quercus*]; idem, Wagon Wheel Forest Cp. (1, FSCA). COCHISE Co.: 5 mi W Portal (1, CDAE) [blacklight]. Chiricahua Mts. (3, FSCA, MCZ); idem, W of Portal (1, FSCA) [bark]. COCONINO Co.: Grand Canyon Nat. Pk. (1, CDAE) [ex bark-ground cover]. GILA Co.: Payson (7, CAS) [under bark of rotten oak stump]. Pinal Mts. (2, USNM). SANTA CRUZ Co.: Santa Rita Mts. (3, CAS); idem, Madera Cyn. (5, FSCA). Pajarito Mts., Sycamore Cyn. (3, FSCA) [under bark oak]; idem, Pena Blanca (1, FSCA) [under bark oak]. PIMA Co.: Santa Catalina Mts., Redington Pass (2, FSCA) [under bark hackberry]; idem, Bear Canyon (7, FSCA) [under bark oak/pine]; idem, Peppersauce Cyn. (1, FSCA) [under bark oak]. “Graham Mts., Wet Cyn.” (1, FSCA). CALIFORNIA. “Cal.” (37, AMNH, CAS, INHS, MCZ, USNM). ALAMEDA Co.: county record only (11, CAS, FMNH, MCZ). Berkeley (61, CAS, CUIC). Alameda (3, CAS, FMNH). Oakland (2, USNM). Tracy

(1, USNM) [under bark]. Redwood Canyon (1, CAS). *BUTTE Co.*: Chico (1, CDAE) [ex raisin trap]. Paradise (1, CAS). *CALAVERAS Co.*: 4.8 km S West Point (1, CAS). Mokelumne Hill (16, CAS). *COLUSA Co.*: 3 mi S Lodoga (3, CDAE) [ex *Polyporus sulphureus*]. *CONTRA COSTA Co.*: Vine Hill (22, CAS). Mt. Diablo (5, CAS) [*Quercus dingsolepis*]. *EL DORADO Co.*: county record only (1, USNM) [under bark of *Pinus sabiniana*]. 3 mi W Grizzly Flat (4, CDAE) [under oak bark/reared from polypore on *Pinus* sp.]. 2 mi. S Kyburz (1, CDAE). 5 mi E Volcanoville (4, CDAE). 2 mi NE Auburn (60, CDAE) [under bark of standing, burn killed *Pinus/Quercus*]. 6 mi SW Ice House (1, CDAE) [conifer bark]. 3 mi S Somerset (1, TAMU). 1.2 mi W Stumpy Meadows Lake (2, CDAE) [under bark *Abies concolor*]. Pollock Pines (1, OSUC). Pine Hill nr Rescue (1, OSUC). Lake Edson (3, CDAE) [under *Pinus* bark]. *FRESNO Co.*: county record only (1, CAS). Clovis (1, USNM). 3 mi NE Auberry (1, CDAE) [under bark of *Quercus*]. Huntington Lake (1, CAS). 10 mi N Parkfield (2, CDAE) [under *Pinus* bark]. *HUMBOLDT Co.*: county record only (2, USNM). 5 mi NW Garberville, (2, CDAE) [malaise trap]. Green Point (1, CAS). Fieldbrook (1, USNM). Hydesville (1, CAS). *KERN Co.*: county record only (2, USNM). *LAKE Co.*: county record only (2, CAS). Clearlake Oaks (3, CAS, CDAE) [ex Digger pine]. Lucerne (2, CAS). *LASSEN Co.*: Pine Cr. (6, CAS). Facht (1, CAS). *LOS ANGELES Co.*: county record only (6, CAS, USNM). Sierra Madre (1, CAS). San Gabriel Canyon (2, CDAE). Los Angeles (8, CAS, CUIC). Pasadena (21, AMNH, CAS, CUIC, FMNH, MCZ). Long Beach (2, CAS) [on lichens]. San Dimas Exp. For. (3, CAS). 2 mi E Three Points (13, CDAE) [under oak bark]. Pomona (4, INHS). Jackson Lake (1, MCZ). *MADERA Co.*: Placer Ran. St. (1, CAS) [*Alnus rhombifolia*]. Anderson Valley (1, CAS) [*Quercus californica*]. *MARIN Co.*: county record only (10, CAS, CUIC). Mill Valley (2, CAS) [rotting tomato]. Novato (2, CAS) [ultraviolet light]. Taylorville (3, CUIC). Lagunitas (1, CAS). Muir Woods (1, CAS). Bon Tempe Lake (1, CAS). Inverness (3, CAS). Stinson Beach (1, CAS). Alpine Dam (1, CAS). L. Lagunitas Rd. (2, CAS). Lagunitas (1, MCZ) [ex *Lenzites betulina*]. Carson Ridge (1, MCZ) [*Polystictus versicolor* on *Umbellularia*]. *MARIPOSA Co.*: 1.5 mi NE Darrah (1, CDAE) [under bark *Pinus*]. Mariposa (4, CDAE) [ex *Plantanus*]. Anderson Valley (3, CAS) [*Libocedrus decurrens*]. Yosemite Nat. Pk. (1, CAS). *MENDOCINO Co.*: county record only (1, CAS). 6 mi N Willits (1, MCZ) [ex *Polyporus sulfureus*]. *MERCED Co.*: 2 mi E Cressey (7, CDAE) [under bark *Populus tremuloides*]. Los Banos Valley (15, CDAE) [under *Populus/Salix*/Cottonwood bark]. *MONTEREY Co.*: 4 mi SE Nottleys Landing (3, CDAE) [ex polypore fungus]. Soledad (1, CDAE) [on *Pleurotus ostreatus*]. 2.4 mi N Parkfield (10, CDAE) [fungus under bark of *Populus*]. Bradley (1, CDAE). Jamesburg (2, AMNH). Carmel (5, CAS). Big Sur (5, CAS). *NAPA Co.*: Capella Cr. (6, CDAE). 3 mi NW Lake Berryessa (22, CDAE) [under bark standing fire killed *Pinus sabiniana*]. 2 mi NNE Angwin (24, CAS) [stump of *Quercus kelloggii*/on rotting apple/under bark of *Pinus ponderosa*/under pile of weeds]. Pope Valley (1, OSUC). *NEVADA Co.*: Sagehen Cr. (7, FSCA, OSUC). Truckee (1, USNM). *PLACER Co.*: county record only (3, CAS). Folsom Lake (2, CDAE) [ex *Pleurotus ostreatus*]. 5 mi S Auburn (1, CDAE) [berlesed from oak duff]. *PLUMAS Co.*: county record only (1, USNM) [pine bark]. 6 mi N.W. Chester (1, USNM). *RIVERSIDE Co.*: 2 mi NW Gilman Hot Springs (1, CDAE). Hemet (2, CDAE). Glenlvy Hot Spr. (2, CAS). Riverside (2, CAS, CUIC). Hempt Res. (1, CAS). *SACRAMENTO Co.*: county record only (1, USNM). Sacramento (4, CDAE). Sacramento River (1, CDAE) [barking Riparian Woodland]. *SAN BERNARDINO Co.*: county record only (4, OSUC). Colton (3, USNM). San Antonio Creek (4, CDAE). N Ceder Springs (3, CDAE). Oak Glen (2, CDAE). Chino Hills, Carbon Canyon (1, FSCA) 1. *SAN DIEGO Co.*: country record only (2, CDAE, FMNH) [1—peach]. Warner Springs (2, AMNH). Poway (2, CAS). Banner (3, CAS). Burnt Rancheria P.C. (1, USNM). Mts. near Clairemont (3, FMNH, MCZ). *SAN FRANCISCO Co.*: San Francisco (17, CAS, CUIC, USNM). *SAN LUIS OBISPO Co.*: 1 mi SW Cholame (4, CDAE) [under bark, oak stump]. 2.8 mi S Atascadero (1, CDAE). *SAN MATEO Co.*: Crystal Springs L. (1, CAS). Stanford (5, CAS). *SANTA BARBARA Co.*: Santa Barbara (1, CAS). Santa Cruz Isl. (4, FSCA) [1—*Quercus agrifolia*]. *SANTA CLARA Co.*: county record only (1, USNM). Stevens Ck. (1, CAS). Los Gatos (10, CAS, USNM). Alum Rock Park (1, USNM). Gilroy Hot Spg (1, CAS). *SANTA CRUZ Co.*: 9 mi NE Big Basin (12, CAS). Ben Lomond (1, CAS). Felton (4, USNM) [under bark]. *SHASTA Co.*: county record only (7, FMNH). Redding (1, CDAE). *SISKIYOU Co.*: county record only (3, CAS). Soda Springs (1, CAS). Dorris (2, AMNH) [pine stump]. McCloud (1, CAS). Antelope Cr. (1, CAS). Lava Beds National Monument (Mammoth Crater) (2, AMNH) [under bark]. *SONOMA Co.*: county record only (5, MCZ, USNM). Duncan Mills (1, CAS). Cazadero (1, CUIC). Sobre Vista (1, CAS). Santa Rosa (3, AMNH, CDAE). *SUTTER Co.*: country record only (1, CDAE) [collected from peach]. *TEHAMA Co.*: Red Bluff (6, CAS, OSUC). 12 mi SW Red Bluff (4, OSUC). *TRINITY Co.*: county record only (1, CAS). Waeverville (1, CDAE). Carrville (1, CAS). 12 mi SE Hyampom

(1, CAS). *TULARE Co.*: Ash Mountain (3, CDAE). Clough Caves (1, CAS). Kaweah (5, CAS). Colony Mill (1, CAS). *VENTURA Co.*: Ojai (1, MCZ). *YUBA Co.*: Spenceville Wildlife Area (10, CDAE) [under oak bark]. 15 mi E Marysville (5, CDAE) [antifreeze pit trap]. "Clayton" (2, CAS). "Santa Cruz Mts." (20, CAS, FMNH, MCZ, USNM). "Norval Flats" (1, CAS). "Alder, San Antonio Can., San Berdo. Mts." (2, CAS). "Warners" (2, CAS). "Malibou Beach" (6, CAS). "Northfork" (9, CUIC). *COLORADO. ROUTT Co.*: Steamboat Springs (1, CAS) [under aspen bark]. *IDAHO. ADA Co.*: Barber Park (3, FSCA). *CANYON Co.*: Parma (1, USNM). *KOOTENAI Co.*: Coeur d'Alene (10, AMNH, MCZ, USNM). *NEBRASKA. DAWES Co.*: Pine Ridge (1, USNM). *NEVADA*. State record only (3, AMNH, USNM). *LYON Co.*: Dayton (8, AMNH, MCZ) [bark dead *Populus*]. *STOREY Co.*: 6 mi Canyon, Virginia City (2, TAMU). *WASHOE Co.*: Reno (2, AMNH). *NEW MEXICO. TAOS Co.*: San Juan Valley (3, MCZ). *OREGON*. "Or" (7, CMNH, FMNH, INHS, MCZ). *BAKER Co.*: Dooley Mt. (4, AMNH). *BENTON Co.*: Monroe (2, USNM) [in flight]. 2 mi W Corvallis (13, AMNH) [under dead oak bark]. *GRANT Co.*: John Day (2, AMNH). *HOOD RIVER Co.*: Hood River (4, USNM). *JACKSON Co.*: Medford (1, CAS). Shady Cove (1, AMNH) [under oak bark]. *JOSEPHINE Co.*: Illinois River (1, AMNH). *KLAMATH Co.*: Klamath Falls (12, AMNH) [under bark juniper stump]. 15 mi NW Bly (3, AMNH) [on yellow pine]. Upper Klamath Lake (17, AMNH) [dead poplar bark]. Merrill (1, AMNH) [tree litter]. Hildebrand (6, AMNH) [pine bark]. 7 mi W Keno (1, AMNH) [under bark]. *YAMHILL Co.*: county record only (2, CAS, USNM). *TEXAS. Dallas Co.*: DALLAS (1, MCZ). *UTAH. SUMMIT Co.*: Park City (1, USNM). *UTAH Co.*: Mt. Timpanogos (1, CAS). East Utah Lake (7, TAMU). *WASHINGTON*. "Wash" (2, OSUC). *GRAYS HARBOR Co.*: Hoquiam (1, USNM). *OKANOGAN Co.*: Omak (1, MCZ). *SPOKANE Co.*: 9 mi N Spokane (1, FMNH). *THURSTON Co.*: Olympia (6, MCZ). Tenino (2, USNM). *WHITMAN Co.*: Wawawai Cyn (2, LSUC). Pullman (4, USNM).

HESPEROBAENUS RUFIPES LeCONTE, 1863

Hesperobaenus rufipes LeConte, 1863: 65. Type locality: «southern states». Horn (1879: 263); Blatchley (1910: 669); Downie & Arnett (1996: 988).

Type Material.—LeConte (1863) described *H. rufipes* from an unspecified number of specimens. His collection (in MCZ) contains two specimens. The first one, a male, is labelled "[orange disc]/Type 7045/*H. rufipes* Lec. [handwritten]". The second, also a male, has an orange disc only.

Description.—Body length: 2.0–2.8 mm. *Coloration*.—Dorsal surface uniformly red-brown. *Microsculpture*.—Prosternal apophysis without microsculpture. *Head*.—Wider in males (WH/WP = 0.98–1.05; $\bar{x}$ = 1.02; n = 10) than in females (WH/WP = 0.91–0.98; $\bar{x}$ = 0.94; n = 10). Eye convex, longitudinal diameter 1.4–1.5 $\times$ length of antennomere I. Temple short, about 0.4 $\times$ longitudinal diameter of eye, and slightly produced posteriorly (Fig. 17). Antennomere IX slightly wider than long, slightly narrower than antennomere X. *Prothorax*.—Pronotum transverse (LP/WP = 0.90–0.96; $\bar{x}$ = 0.93; n = 20), with maximal width before apex, at apical 4/5; anterior angle rounded, not produced (Fig. 17); punctures narrowly spaced laterally but not subcontiguous; disc slightly convex, with rather wide median impunctate area. Hypomeron not rugose. *Elytra*.—Proportionally long (LE/LP = 2.17–2.33; $\bar{x}$ = 2.24; n = 20), with oblique depression on anterior third near suture. Strial punctures rather coarse and deep. Third and fifth intervals with 0–2 setigerous punctures at base. Scutellum without setigerous punctures. *Abdomen*.—First visible sternite with coxal bead triangularly produced, without or with short longitudinal extension. Male last visible sternite without median depression. *Male Genitalia*.—Aedeagus as in Fig. 14.

Diagnosis.—Distinguished from other *Hesperobaenus* treated by features given in the key to species.

Distribution.—This species occurs from Maryland to Kansas, south to Florida and Texas (Fig. 19).

Habitat.—Found under the bark of oak and maple trees. Blatchley (1928: 66) reported that this species occurs frequently, around Dunedin, Florida, "beneath the close fitting bark of dead water-oak".

Material Examined.—ALABAMA. “Ala” (1, MCZ). *DEKALB Co.*: De Soto State Park (2, CAS). *JEFFERSON Co.*: Birmingham (1, FMNH). *LAUDERDALE Co.*: county record only (1, CNC). *LEE Co.*: county record only (2, LSUC). *MOBILE Co.*: Mobile (1, MCZ). *TUSCALOOSA Co.*: county record only (3, CNC). “Spring Hill” (5, OSUC, USNM). ARKANSAS. *HEMPSTEAD Co.*: Hope (2, MCZ). *JOHNSON Co.*: Ozone (3, TAMU). *LOGAN Co.*: Mt. Magazine Lookout (1, CNC) [sifting deciduous leaf litter]. *WASHINGTON Co.*: county record only (6, INHS). Fayetteville (10, INHS). DISTRICT OF COLUMBIA. “DC” (2, MCZ). Washington (1, USNM). FLORIDA. “Fla” (1, INHS). *ALACHUA Co.*: county record only (5, CUIC). San Felasco Hammock (8, FSCA). Gainesville (2, FSCA). “At Levy Co. line SR 24” (6, FSCA) [under bark of *Quercus* sp.]. *COLLIER Co.*: Chokoloskee (4, CUIC, MCZ). *COLUMBIA Co.*: county record only (1, FSCA) [under bark of dead *Quercus laevis*]. *DUVAL Co.*: county record only (11, FSCA) [under bark of *Quercus*]. *MARION Co.*: Rainbow Springs (34, FSCA). Ocala (1, FSCA). *OKALOOSA Co.*: Fort Walton Beach (6, CNC). Niceville (1, CNC). Nr. Deerland (14, FSCA) [turkey oak bark]. “0.3 mi N jct US 90 & CR 345” (40, FSCA) [under bark of *Quercus laevis*]. *PINELLAS Co.*: Dunedin (5, AMNH, MCZ, USNM). GEORGIA. “Geo” (1, MCZ). *CHATHAM Co.*: Savannah (1, MCZ) [under bark and in fungi]. *HABERSHAM Co.*: Cornelia (1, USNM) [*Quercus*]. *JEFFERSON Co.*: Louisville (1, USNM) [under bark]. *LAMAR Co.*: Barnesville (2, MCZ). ILLINOIS. *LA SALLE Co.*: Starved Rock (1, FMNH). *UNION Co.*: Anna (1, INHS). *VERMILION Co.*: Muncie (5, USNM). KANSAS. *LEAVENWORTH Co.*: Leavenworth (2, CAS, CNC). KENTUCKY. *HENDERSON Co.*: Henderson (1, CAS). LOUISIANA. *CADDO Parish*: parish record only (1, LSUC). *MADISON Parish*: Tallulah (1, USNM). “Vowell’s Mill” (18, MCZ). “Bay Sara” (4, USNM). MARYLAND. *BALTIMORE Co.*: Catonsville (5, USNM) [under bark of hickory log]. *MONTGOMERY Co.*: 3 mi S Colesville (1, MCZ) [under bark maple]. *PRINCE GEORGES Co.*: county record only (1, USNM). Hyattsville (1, USNM). MISSISSIPPI. *FORREST Co.*: Hattiesburg (3, AMNH). *GEORGE Co.*: Lucedale (77, CUIC). *GREENE Co.*: Avera (5, CUIC). MISSOURI. “Mo” (2, CAS, USNM). *St. Louis City*: St. Louis (2, USNM). NORTH CAROLINA. “N.C.” (11, MCZ, OSUC, USNM). *CLEVELAND Co.*: Kings Mountain (1, TAMU). *FRANKLIN Co.*: county record only (1, FSCA). *MOORE Co.*: Southern Pines (3, USNM). *POLK Co.*: Tryon (6, USNM)

[*Hicoria*]. WAKE Co.: Raleigh (5, FSCA). OHIO. DELAWARE Co.: county record only (1, FSCA). HOCKING Co.: county record only (4, OSUC). OKLAHOMA. CADDO Co.: county record only (1, CAS). CHEROKEE Co.: 5 mi NE Qualls (1, CAS). LATIMER Co.: county record only (29, FSCA, NHDE, USNM) [2—under oak bark]. 5 mi W Red Oak (3, FSCA). PAYNE Co.: Stillwater (1, MCZ). PITTSBURG Co.: McAlester Army Ammunition Plant (1, OSUC). PENNSYLVANIA. ALLEGHENY Co.: Pittsburgh (2, CMNH). SOUTH CAROLINA. “SC” (2, MCZ). PICKENS Co.: Clemson (19, CAS, TAMU) [under oak bark/under bark]. Rocky Bottom (3, USNM). TENNESSEE. CUMBERLAND Co.: 8 km NW Rockwood (3, USNM). TEXAS. “Tex” (6, MCZ, USNM). CHAMBERS Co.: Anahuac (1, USNM). DALLAS Co.: Dallas (1, MCZ). HARRIS Co.: Katy (8, FSCA). Houston (1, USNM). KERR Co.: Kerrville (20, USNM). JEFFERSON Co.: Beaumont (2, USNM). MONTGOMERY Co.: Conroe (8, FSCA). TRAVIS Co.: Austin (4, CAS). VICTORIA Co.: Victoria (1, USNM). “Cypress Mills” (1, MCZ). VIRGINIA. CAROLINE Co.: Ladysmith (11, AMNH). PAGE Co.: Luray (1, FMNH). WEST VIRGINIA. PENDLETON Co.: Smoke Hole (1, CUIC) [light trap].

HESPEROBAENUS CONSTRICTICOLLIS BOUSQUET, NEW SPECIES

Type Material.—Holotype (♂) labelled: “TEX: Cameron Co. Sabal Palm Grove Sanct., IV-8-1994 Coll. E.G. Riley/from Sabal Palm Grove [handwritten]/E.G. Riley Collection/Holotype *Hesperobaenus constricticollis* Bousquet”, deposited in Texas A&M University, College Station, Texas.

Description.—Body length: 2.6 mm. *Coloration*.—Head, pronotum and scutellum light red-brown, elytra paler, yellow. *Microsculpture*.—Prosternal apophysis without microsculpture. *Head*.—Wider than pronotum (WH/WP = 1.09). Eye rather large, longitudinal diameter about $1.5 \times$ length of antennomere I. Temple moderately long, about $0.5 \times$ longitudinal diameter of eye, not produced posteriorly (Fig. 8). Antennomere IX as wide as long, narrower than antennomere X. *Prothorax*.—Pronotum transverse (LP/WP = 0.88) with sides markedly narrowed in posterior half; anterior angle rounded, not produced (Fig. 8); punctures rather distantly spaced laterally, not subcontiguous; disc flat, with moderately wide, median impunctate area, widening in posterior half. Hypomeron rugose. *Elytra*.—Moderately long (LE/LP = 1.84), without oblique impression on anterior third. Third and fifth intervals with 0–2 setigerous puncture at base; scutellum without setigerous puncture. *Abdomen*.—First visible sternite with coxal bead not triangularly produced but thickened, without longitudinal extension. Male first abdominal sternite with small tuft of short (but longer than adjacent ones) setae at middle. Male last visible sternite without depression. *Male Genitalia*.—Aedeagus as in Fig. 15.

Diagnosis.—Distinguished from other *Hesperobaenus* treated by the markedly narrowed pronotum posteriorly.

Etymology.—The specific name derives from the Latin *constrictus*, *a*, *um* (constricted) and *collum*, *-i* (used for pronotum); it refers to the markedly narrowed sides of pronotum toward base.

Distribution.—This species is known only from the type locality. The Sabal Palm Grove Sanctuary is located in a bend of the Rio Grande along the United States–Mexico border, near Brownsville, in southeastern Texas.

Habitat.—The species may be associated with Sabal Palms.

Material Examined.—See Type Material.

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Scientific Note

PHYTOSEIID MITE FAUNA ON GORSE, *ULEX EUROPAEUS* L., IN WESTERN OREGON, USA WITH NEW RECORDS FOR *PHYTOSEIULUS PERSIMILIS* ATHIAS-HENRIOT AND *AMBLYSEIUS GRAMINIS* (CHANT) (ACARI: PHYTOSEIIDAE)

Gorse, *Ulex europaeus* L. (Fabaceae), is a spiny evergreen shrub native to western Europe. The plant was intentionally introduced into coastal regions of southern Oregon (USA) in the late 1800s. Since its introduction, *U. europaeus* has escaped cultivation and aggressively invaded natural and disturbed habitats in western North America, including British Columbia, Washington, Oregon, northern California, and Hawaii. In an effort to suppress this weed, the European native spider mite *Tetranychus lintearius* Dufour (Acari: Tetranychidae) was introduced into gorse-dominated habitats of western Oregon in 1994 (Rees, N. E., P. C. Quimby, Jr., G. L. Piper, E. M. Coombs, C. E. Turner, N. R. Spencer & L. V. Knutson. 1996. Biological Control of Weeds in the West. Western Society of Weed Science, Bozeman, Montana).

Establishment, persistence, and efficacy of weed suppression by an introduced biological control agent can be affected by mortality from predators, parasites or pathogens acquired in the adventive range of the agent (Goeden, R. D. & S. M. Louda. 1976. Annu. Rev. Entomol., 21: 325–342). Predatory mites (Phytoseiidae), for instance, suppress spider mites in managed and unmanaged ecosystems worldwide (Helle, W., & M. W. Sabelis. 1985. Spider Mites: Their Biology, Natural Enemies and Control. Elsevier, Amsterdam). Unfortunately, the phytoseiid fauna in most natural habitats is poorly known. Therefore, we sought to determine which predatory mites are associated with the invasive weed *U. europaeus* and its biological control agent *T. lintearius* in western Oregon.

Surveys for phytoseiids were performed at six (four coastal and two inland) sites in western Oregon: near Astoria, Baker Beach, Bandon, Clackamas, Elk River, and Sutherlin (Table 1). Monthly surveys were performed at Baker Beach, Bandon, and Sutherlin from March 1998 through March 1999 and single surveys were conducted at the remaining sites. Surveys consisted of sampling *U. europaeus* branches every 10 m along a randomly selected 100 m transect. A total of 20 samples were collected from each transect by randomly selecting two independent terminal *U. europaeus* branches at each sampling point and excising ca. 25 cm of foliage from each branch. Each sample was placed into a polyethylene bag, transported to the laboratory, and branches were individually washed to extract arthropods within 48 h. The extraction method entailed placing individual *U. europaeus* branches in separate one-liter jars and adding 300 ml of 70% ethanol (Pratt, P. D. & B. A. Croft. 2000. Environ. Entomol., 29: 1034–1040). Lids were placed on the jars and shaken manually for 30 sec, left to rest for 1 min, and then shaken again for 30 sec. Plant material was removed with forceps and slowly rinsed with 70% ethanol over jars. The ethanol and associated contents were poured into a Whatman No. 4 filter paper funnel, gravity filtrated, and examined

Table 1. Phytoseiid mites collected from *Ulex europaeus*.

Species	Life style type ¹	Research site	GPS coordinates ²
<i>Amblesius andersoni</i> (Chant)	III	Baker Beach	44.0915 N 124.1158 W
<i>Neoseiulus fallacis</i> (Garman)	II	Baker Beach	44.0915 N 124.1158 W
<i>Typhlodromus pyri</i> Scheuten	III	Sutherlin	43.3970 N 123.2974 W
<i>Amblyseius graminis</i> (Chant)	III ³	Astoria	46.2783 N 123.9970W
<i>Typhlodromus arboreus</i> (Chant)	III	Baker Beach, Bandon, Elk River	(see above and below)
<i>Phytoseiulus persimilis</i> Athias-Henriot	I	Bandon	43.0543 N 124.4083 W
<i>Galendromus occidentalis</i> (Nesbitt)	II	Clackamas	45.2391 N 122.4268 W

¹ Type I = specialized predators of *Tetranychus* species; Type II = selective predators of tetranychid mites, particularly with those that produce copious webbing; Type III = generalist predators.
² Global positioning system in decimal degrees (Elk River: 24.7648 N 124.4626 W).
³ Probable classification, life history studies needed to quantify life style type.

within 5 min under a binocular microscope at 40× magnification. All phytoseiid mites that were washed from branches were mounted on glass slides in Hoyer’s media and identified according to morphological characters (Schuster, R. O., and A. E. Pritchard. 1963. *Hilgardia*, 34: 191–194).

In preliminary samples, the predatory mite *Phytoseiulus persimilis* Athias-Henriot was collected at the Bandon survey site. This phytoseiid is a specialist predator that feeds primarily on spider mites that belong to the genus *Tetranychus* (McMurtry, J. A. & B. A. Croft. 1997. *Annu. Rev. Entomol.*, 42: 291–321) and it is the most common biological control agent released for suppression of pest mites in agricultural and horticultural systems throughout the world (Helle & Sabelis 1985). Because of the potential for *P. persimilis* to suppress the beneficial *T. lintearius*, we sought to assess the geographic range of this predatory mite in southern Oregon. This was done on 15 Sept. 1998 by sampling foliage of *U. europaeus* (as described earlier) every 1.6 km along a N-S transect radiating from the epicenter at each study site. To increase the probability of collecting *P. persimilis* and accurately measure its geographic distribution, only *U. europaeus* foliage containing colonies of *T. lintearius* was selected at each survey point. Transects were extended north and south until three consecutive samples failed to

Table 2. Dominant predatory mite species collected at each survey site.

Site name	Species	Peak density ¹	Month ²
Astoria	<i>Amblyseius graminis</i>	0.45 (0.13)	April ³
Baker Beach	<i>Typhlodromus arboreus</i>	2.28 (0.52)	May
Bandon	<i>Phytoseiulus persimilis</i>	2.75 (2.02)	October
Clackamas	<i>Typhlodromus arboreus</i>	0.51 (0.28)	September ³
Elk River	<i>Typhlodromus arboreus</i>	1.50 (1.19)	July ³
Sutherlin	<i>Typhlodromus pyri</i>	4.65 (0.90)	July

¹ Peak densities of phytoseiid mites per sample, mean (SE).
² Month when peak density was recorded.
³ Because only a single sample was collected from these sites, Peak density and Month many not accurately describe the population densities.

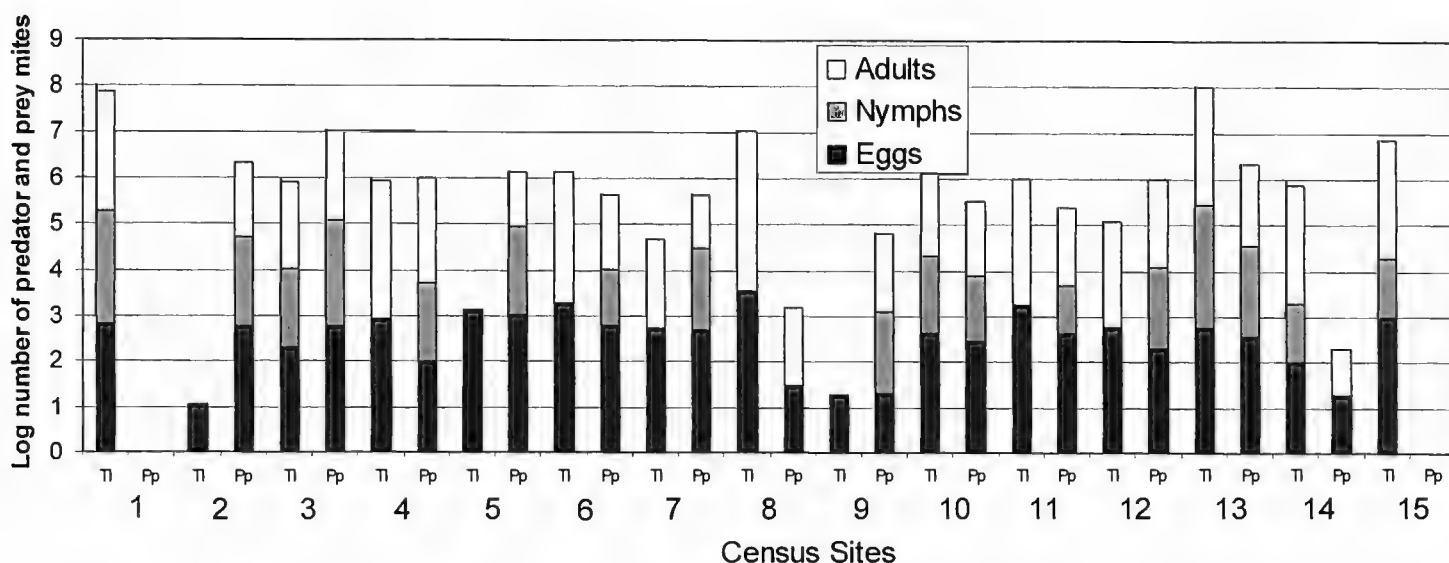


Figure 1. Predator-prey ratios and age distribution for *Tetranychus lintearius* (T1) and *Phytoseiulus persimilis* (Pp) along a north (15) to south (1) transect (7 = initial spider mite release site) during a 1999 survey of the invasive weed *Ulex europaeus* in Bandon, Oregon (U.S.A.).

produce the predatory mite or *T. lintearius* populations were no longer present. Extraction and identification of arthropods was performed as described above.

Among the Phytoseiidae collected during 1998 and 1999, 57% of the species were generalists (Type III) species, which feed on various mites, insects, and pollens (Table 1, McMurtry & Croft 1997). These generalist predators were also the dominant (most abundant) species at five of the six survey sites (Table 2). At the Bandon site, however, the specialist Type I predator of *Tetranychus* species, *P. persimilis*, was the most common natural enemy collected from *T. lintearius* colonies.

To our knowledge, this is the first detailed survey of phytoseiid mites along the coastal regions of Oregon. Findings from this survey included the first collection of *Amblyseius graminis* (Chant) in North America. This predatory mite is endemic to the Old World and explanations for its adventive geographic distribution in the Pacific Northwest remain unclear. Although collected from *T. lintearius* colonies, attempts to establish a laboratory culture of *A. graminis* when held with the spider mite were unsuccessful, suggesting that the predator may not readily feed on this spider mite and thus is unlikely to interfere with biological control.

The distribution of *P. persimilis* in southern Oregon appears to be limited to a 20.8 km transect centered in the city of Bandon. Census site 7 in Fig. 1 represents the Bandon study site, with the predatory mite distributed 11.2 km north and 8 km south. *Phytoseiulus persimilis* densities along the sampled transect were similar to those of *T. lintearius* ($t = 0.46$, $df = 24$, $P = 0.65$), when the extreme sample locations 1 and 15 are excluded from the analysis. Predator-prey ratios and age distributions at each census site are also presented in Fig. 1. These data reflect a distribution of life stages of a predator population that was rapidly increasing over most of the range of sample sites. It should be noted that, at sites 1 and 15, there were prey mites but no predator mites. *Phytoseiulus persimilis* had not yet expanded into these outer limits and thus the distribution of prey life stages reflected the reproduction of the spider mite without major predation influences. Also note that, within the area where *P. persimilis* is distributed, there were three sites (2, 5, and 9; Fig. 1) where prey mite populations were decreased by

predation to the extent that there were only adult mites, and all egg and immature life stages (preferred life stages for *P. persimilis*) had been eliminated.

This is the first report of *P. persimilis* occurring in natural systems of Oregon, and possibly the first record north of the Sacramento Valley, California. The geographic distribution of *P. persimilis* in Oregon presently appears to be limited to the vicinity of the city of Bandon. Possible explanations for this recent occurrence include introductions by horticulturalists for spider mite control in glass-houses or ornamental plants. An alternative, but less likely, explanation is that *P. persimilis* populations naturalized in the region but remained undetected until sufficient populations of prey species had increased by the recent introduction of *T. lintearius*. Although often considered a semitropical species, the survival of *P. persimilis* during recent atypically cool winters ($< -5^{\circ}\text{C}$) suggests that it has extended its geographic range to include coastal regions of western Oregon.

In general, these findings suggest that *T. lintearius* has developed new associations with generalist and specialist predatory mites. However, association among these mites is not sufficient evidence to conclude that phytoseiids are negatively impacting *T. lintearius*, and thus biological control of gorse. Additional data describing prey suitability and field-based exclusion tests are needed to quantify the impacts of phytoseiids on the biological control agent *T. lintearius*.

Records.—OREGON. CLATSOP Co. Astoria, 4 Apr 1998, E. M. Coombs, *Amblyseius graminis*, branches of *Ulex europaeus*.

COOS Co. Bandon, 17 Mar 1998, P. D. Pratt, *Phytoseiulus persimilis*, branches of *Ulex europaeus*.

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- Blackman, R. L., P. A. Brown & V. F. Eastop. 1987. Problems in pest aphid taxonomy: can chromosomes plus morphometrics provide some answers? pp. 233–238. In Holman, J., J. Pelikan, A. G. F. Dixon & L. Weismann (eds.). Population structure, genetics and taxonomy of aphids and Thysanoptera. Proc. international symposium held at Smolenice Czechoslovakia, Sept. 9–14, 1985. SPB Academic Publishing, The Hague, The Netherlands.
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- Sorensen, J. T. (in press). Three new species of *Essigella* (Homoptera: Aphididae). *Pan-Pacif. Entomol.*

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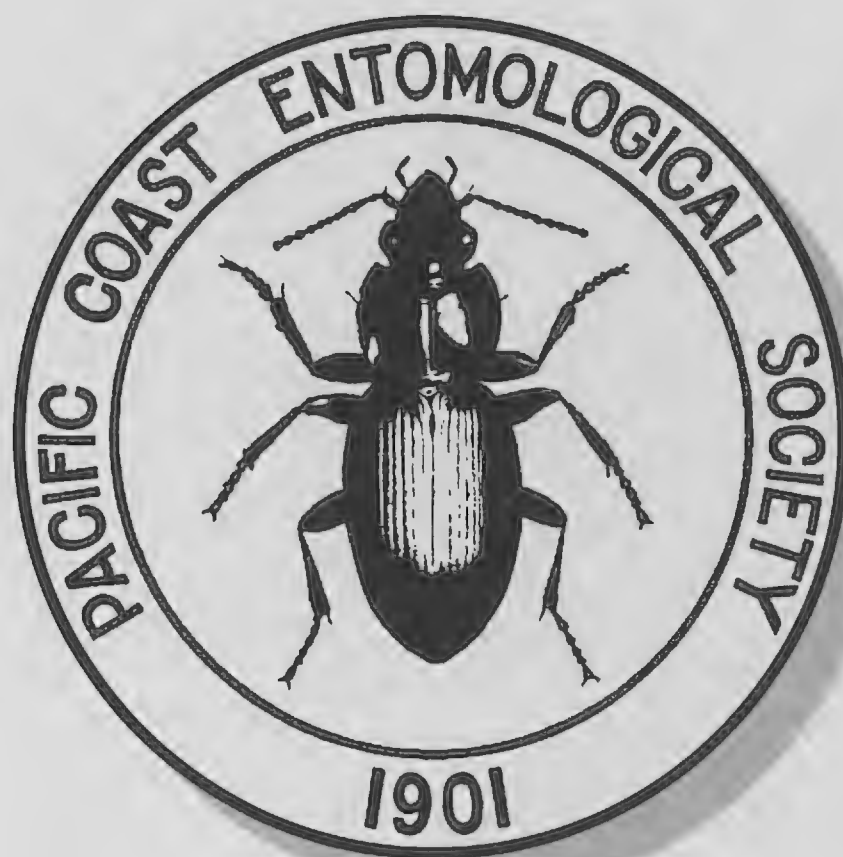
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ALLOZYME PHYLOGENY OF NORTH AMERICAN COPPERS (LYCAENINAE: LYCAENIDAE)

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Abstract.—Phylogenies were created with allozyme data of 15 species and two subspecies of North American coppers. Most of the species align with the currently recognized subgenera of the subfamily Lycaeninae. These subgenera exhibit a significant level of genetic differentiation that is perhaps equivalent to genera. The subgenus *Epidemia* unexpectedly includes *Lycaena hyllus* (Cramer), which is currently assigned to a separate monotypic subgenus. The Nei Distance tree separates the North American taxa into two distinct biological groups. One group diapauses as partially grown larvae and has its closest relatives in the Palaearctic based on morphological data. The other group is endemic and diapauses in the egg stage (first instars within eggs). Divergence within the Distance Wagner tree parallels unique host shifts that have occurred several times in the North American coppers. Most shifts have originated from a *Rumex* feeding species. The host shift to *Eriogonum* has produced at least two and possibly more species. A few species have adapted to *Vaccinium*; these shifts appear to have occurred independently.

Key Words.—Insecta, *Lycaena*, *Epidemia*, Lycaeninae, host shifts, diapause.

The taxonomy of the North American coppers (subfamily Lycaeninae) has a complex history. In the past two centuries, the species have been classified under several lycaenid genera such as *Polyommatus* Latreille, *Lycaena* Fabricius, *Chrysophanus* Hübner, and *Heodes* Dalman. Miller & Brown (1979) in an attempt to balance taxonomy with a proposed copper phylogeny resurrected genera originally named by Scudder in 1876 (*Tharsalea*, *Chalceria*, *Gaeides*, and *Epidemia*) and also erected monotypic genera (*Hyllolycaena* and *Hermelycaena*) for the species *Lycaena hyllus* and *L. hermes* (W. H. Edwards) respectively. Their subsequent systematic catalogue followed the same trend using a total of seven genera (Miller & Brown 1981). However, a recent checklist of California butterflies conservatively placed all coppers in the genus *Lycaena* with further division provided by the subgenera *Lycaena*, *Epidemia*, *Chalceria*, *Hermelycaena*, and *Tharsalea* (Emmel et al. 1998). These authors did not recognize the subgenus *Gaeides*, because its type species is closely related to the type species of *Chalceria*. *Chalceria* has page priority over *Gaeides* in Scudder (1876).

Miller & Brown (1979) pointed out the primitive features of *Lycaena phlaeas* and *L. cuprea* and speculated on their probable origin in the Palaearctic. The source of North American *L. phlaeas* populations is uncertain, but *L. phlaeas* has many subspecies throughout the Old World, several of which could have served as founders. Regarding *L. cuprea*, Klots (1936) and Sibatani (1974) independently noted a kinship between this North American species and the Eurasian species *L. alciphron* (Rottemburg). Strong similarities exist between these two species in both genitalia and facies. While it is tempting to link *L. cuprea* with *L. alciphron* in a unique Palaearctic genus, the proper generic assignment of *alciphron* is presently uncertain. Modern workers have variably placed it in *Heodes*, *Lycaena*, and

Thersamonolycaena (Higgins 1975, Higgins & Riley 1983, Korshunov & Gorbunov 1995, Tolman 1997, Tusov 2000, Gorbunov 2001). Also of great interest are recently discovered, high altitude Asian species, which display even stronger similarities to *L. cuprea* (Wyatt 1961, Churkin 1999). New studies are needed to resolve the relationship of *L. cuprea* with Palaearctic genera.

Coppers as a whole have a worldwide distribution indicating these butterflies may belong to a very old lineage (Lewis 1973, Miller & Brown 1979). It has been suggested that their earliest divergence began before the continental separation of Pangaea in Late Cretaceous (Miller & Brown 1979). Their distribution presently extends from Eurasia to South Africa, from Asia to New Zealand (including Malayan Peninsula and Papuan region), and from North America to Central America where a single species, *Lycaena (lophanus) pyrrhias* (Godman & Salvin), resides in high elevation cloud forests. They are absent throughout South America and Australia (Clark & Dickson 1971, Miller & Brown 1979, Gibbs 1980, Higgins & Riley 1983, Korshunov & Gorbunov 1995, Gorbunov 2001).

Copper larvae throughout the world, with the exception of North America, feed exclusively on plants in the family Polygonaceae. They chiefly utilize closely related members of the genera *Rumex*, *Polygonum*, and *Muehlenbeckia*. In North America several coppers have shifted onto unique non-polygonaceous hosts, including *Rhamnus* (Rhamnaceae), *Eriogonum* (Polygonaceae), *Ribes* (Grossulariaceae), *Vaccinium* (Ericaceae), and *Potentilla* (Rosaceae) species. Determining what factors caused these butterflies to make host shifts is essential to understanding their evolution.

In this study we produced phylogenies using allozyme analyses of 15 species of North American coppers. We surveyed the various trees for species clusters and compared these clusters for taxonomic congruence with the currently known taxa of the Lycaeninae. We also compared life history features and speculated how some North American coppers may have evolved through diapause changes and host shifts.

MATERIALS and METHODS

Enzyme Analysis.—Fresh or frozen butterflies were homogenized, electrophoresed on 10% starch gels, stained for enzymes, and scored following the procedure of Pratt (1994). The butterfly sample sizes and sites of collection are shown in Table 1. They were stored at -70°C . After removal of the wings the remainders were homogenized in 50 μl of buffer (0.005 M Tris-HCl pH 7.5) per butterfly. The homogenates were stored in microtiter plates at -70°C and electrophoresed on gels with a citrate-aminopropyl-morpholine continuous system (pH 8.5) (Clayton & Tretiak 1972). The enzymes aconitase (ACO-1 & ACO-2), adenylate kinase (AK-1 & AK-2), aspartate amino transferase (AAT-1 & AAT-2), alpha glycerophosphate dehydrogenase (αGPD), glucose phosphate isomerase (GPI), glucose-6-phosphate dehydrogenase (G6PD), hexokinase (HEX-1 & HEX-2), isocitrate dehydrogenase (IDH-1 & IDH-2), malic dehydrogenase (MDH-1 & MDH-2), malic enzyme (ME-1), peptidase [leucyl-glycyl-glycine (PEP-1 & PEP-2) as a substrate], phosphoglucomutase (PGM), and superoxide dismutase (SOD-1, SOD-2, SOD-3) were stained with conventional histochemical stains (Shaw & Prasad 1970). Alleles were scored by distance from the origin.

Analysis of Allelic Variation.—The allelic variations of the 22 presumptive loci

Table 1. Sample sizes and locations of *Lycaena* populations used for enzyme analysis.

Subgenus	Species	N	Location
<i>Chalceria</i>	<i>rubida</i>	8	Bridgeport CA
	<i>xanthoides</i>	3	Southern CA
	<i>editha</i>	8	E Sierra Nevada, CA
	<i>dione</i>	8	Lincoln, Nebraska
	<i>gorgon</i>	8	Frazier Park, CA
	<i>heteronea</i>	8	White Mts., CA
<i>Epidemia</i>	<i>helioides</i>	8	Olancho, CA
	<i>nivalis</i>	13	Sonora Pass, CA
	<i>mariposa</i>	8	Cedar Lake, CA
	<i>epixanthe</i>	5	Chatsworth, NJ
<i>Hyllolycaena</i>	<i>hyllus</i>	9	Ravenwood, MD
<i>Tharsalea</i>	<i>arota arota</i>	6	San Gabriel Mts., CA
	<i>arota nubila</i>	4	Santa Monica Mts., CA
<i>Hermelycaena</i>	<i>hermes</i>	3	San Diego Co., CA
<i>Lycaena</i>	<i>phlaeas</i>	10	Newark, DE
	<i>cuprea</i>	2	Donner Pass, CA

were analyzed as individual genotype data by BIOSYS-1 (Swofford & Selander 1989). Numerous genetic distances (Nei, Nei unbiased, Nei minimum, Nei unbiased minimum, Nei identities, Nei unbiased identities, Rogers, Modified Rogers, Prevosti, Cavalli-Sforza & Edwards chord, Cavalli-Sforza & Edwards arc, and Edwards "E") were produced by BIOSYS-1. Cluster analyses were performed by the method of Sneath and Sokal (1973) using the genetic distances and the following algorithms: unweighted pair-group method with arithmetic averaging (UPGMA), weighted pair-group method with arithmetic averaging (WPGMA), single linkage (SL), and complete linkage (CL). Distance Wagner trees, utilizing the multiple addition criterion algorithm of Swofford (1981), were produced by midpoint rooting with Rogers, Modified Rogers, Prevosti, Cavalli-Sforza & Edwards chord, Cavalli-Sforza & Edwards arc, and Edwards "E" distances (Parris 1972).

RESULTS

The mean number of alleles per locus, percent polymorphic loci, and heterozygosity of North American copper species are shown in Table 2. (A copy of allele frequencies is available upon request.) The mean number of alleles per locus and percent polymorphic loci ranged from 1.1 to 6.7 and 9.1 to 54.5, respectively (Table 2).

Many cluster analysis trees were produced using algorithms and various genetic distances. Trees with the highest cophenetic correlation and lowest standard deviation were identical in topology to the UPGMA tree created with Nei distances (Fig. 1). The Nei Distance tree groups most species into their currently recognized higher taxa. The species *L. rubida* (Behr), *L. xanthoides* (Boisduval), *L. editha* (Mead), *L. dione* (Scudder), *L. gorgon* (Boisduval), and *L. heteronea* Boisduval cluster in the subgenus *Chalceria*. Allied species *L. gorgon* and *L. heteronea* from a distinct separate cluster within *Chalceria*. The species *L. epixanthe* (Boisduval & Le Conte), *L. hyllus*, *L. helioides* (Boisduval) *L. mariposa* (Reakirt), and *L.*

Table 2. Mean number of alleles per locus, percent polymorphic loci, and heterozygosity.

Population	Mean no. of alleles per locus	Mean % of loci polymorphic*	Heterozygosity	
			Direct count	H-W expected**
<i>rubida</i>	1.4 (0.1)	27.3	0.124 (0.049)	0.109 (0.042)
<i>xanthoides</i>	1.2 (0.1)	13.6	0.045 (0.033)	0.079 (0.043)
<i>editha</i>	6.7 (0.2)	50.0	0.195 (0.058)	0.170 (0.046)
<i>dione</i>	1.6 (0.1)	54.5	0.239 (0.064)	0.197 (0.049)
<i>gorgon</i>	6.6 (0.2)	50.0	0.186 (0.052)	0.164 (0.042)
<i>heteronea</i>	6.6 (0.2)	31.8	0.157 (0.061)	0.132 (0.049)
<i>helloides</i>	6.6 (0.2)	40.9	0.146 (0.044)	0.135 (0.040)
<i>nivalis</i>	3.0 (0.0)	18.2	0.076 (0.038)	0.070 (0.033)
<i>mariposa</i>	6.6 (0.2)	45.5	0.102 (0.030)	0.100 (0.030)
<i>epixanthe</i>	1.4 (0.1)	27.3	0.127 (0.048)	0.118 (0.045)
<i>hyllus</i>	1.5 (0.2)	31.8	0.095 (0.035)	0.105 (0.039)
<i>arota arota</i>	1.3 (0.2)	22.7	0.106 (0.045)	0.107 (0.046)
<i>arota nubila</i>	1.3 (0.1)	31.8	0.140 (0.054)	0.138 (0.048)
<i>hermes</i>	1.1 (0.1)	9.1	0.030 (0.021)	0.042 (0.031)
<i>phlaeas</i>	1.5 (0.1)	40.9	0.141 (0.050)	0.116 (0.037)
<i>cuprea</i>	1.3 (0.1)	31.8	0.174 (0.062)	0.174 (0.061)

* A locus is considered polymorphic, if more than one allele was detected.
** Unbiased estimate.

nivalis (Boisduval) cluster in the subgenus *Epidemia*. The species *L. arota* (Boisduval) and *L. hermes* cluster together, however they branch below the branching points of other subgeneric groups suggesting they belong to separate subgenera. *Lycaena phlaeas* and *L. cuprea* constitute a cluster that branches basally to all of the above taxa.

Many Distance Wagner Trees were produced by midpoint rooting with various genetic distances. The tree with the highest cophenetic correlation and lowest percent standard deviation was created with Cavalli-Sforza & Edwards arc distances. It is shown in Fig. 2 with host plants added to right in order to facilitate discussion of host shifts. In this phylogeny *Chalceria* again divides into two distinct clusters with *L. gorgon* and *L. heteronea* forming a closely allied pair. The *Epidemia* align in a fashion similar to the Nei Distance tree with a few subtle differences in branching sequence. *Lycaena epixanthe* clusters with *L. hyllus*,

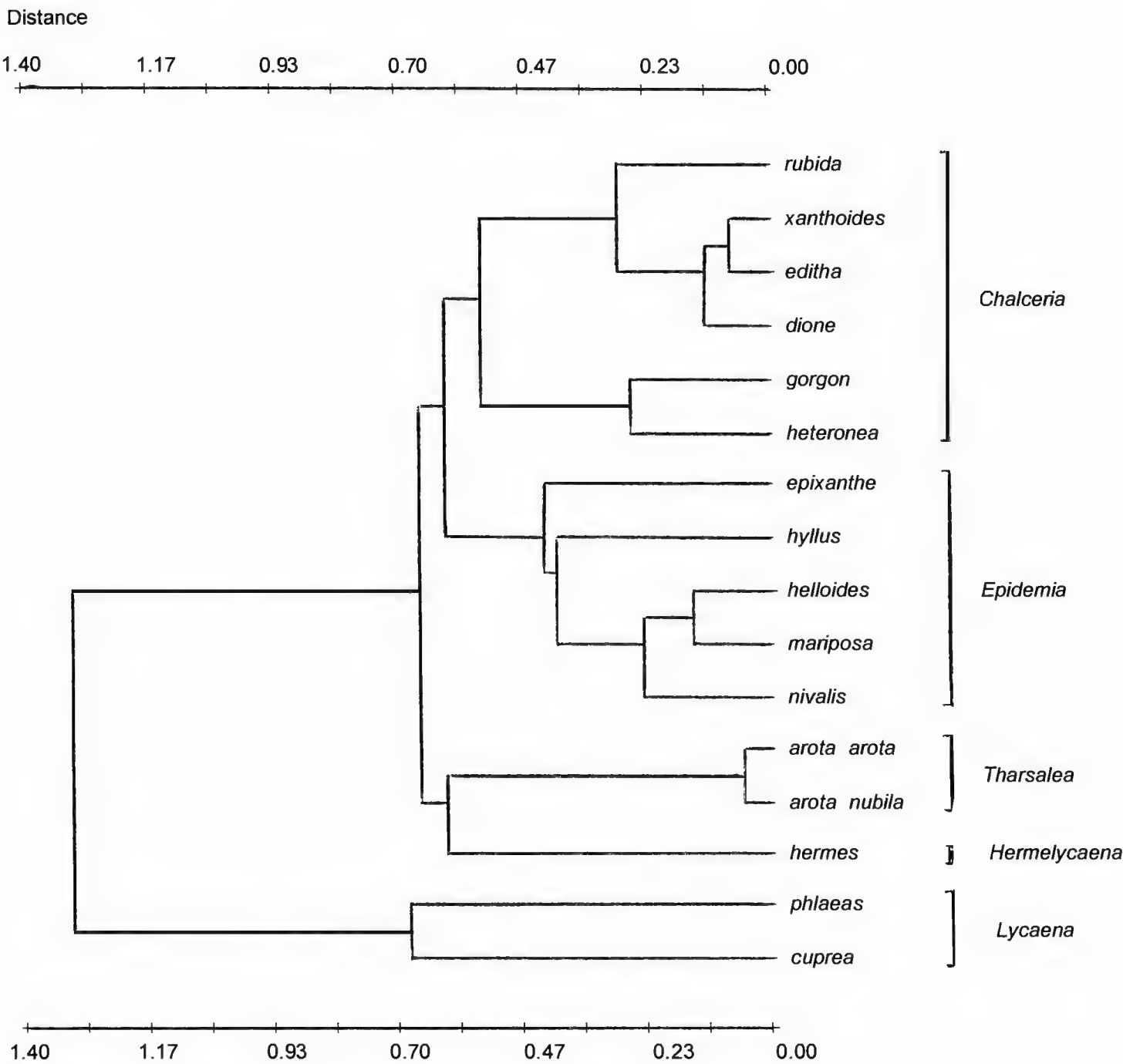


Figure 1. Nei Distance tree. UPGMA tree of 16 North American coppers using Nei distances. Cophenetic correlation 0.925; percent standard deviation 18.896. Subgeneric designations in right margin.

whereas in the Nei Distance tree each species branches independently from the main branch of the group. *Lycaena helloides* clusters with *L. nivalis*, but in the Nei Distance tree it clusters with *L. mariposa*. *Lycaena arota* and *L. hermes* do not cluster together in the Distance Wagner tree. *Lycaena arota* branches from an ancestral stem shared with *Epidemia*, while *L. hermes* branches toward the base of the subfamily just after the *L. phlaeas* and *L. cuprea* branch.

DISCUSSION

Copper Taxonomy.—In our study Nei distances are selected for cluster analysis since they have been used for evolutionary estimates and phylogenies in other arthropods. Despite small sample sizes, which can diminish the overall confidence in results, all of our trees demonstrate regular branching patterns. The trees branch into distinct species clusters with notable levels of genetic differentiation. The topologies of the Nei Distance and Distance Wagner trees (Figs. 1 and 2) show remarkable congruence with the currently recognized North American copper sub-

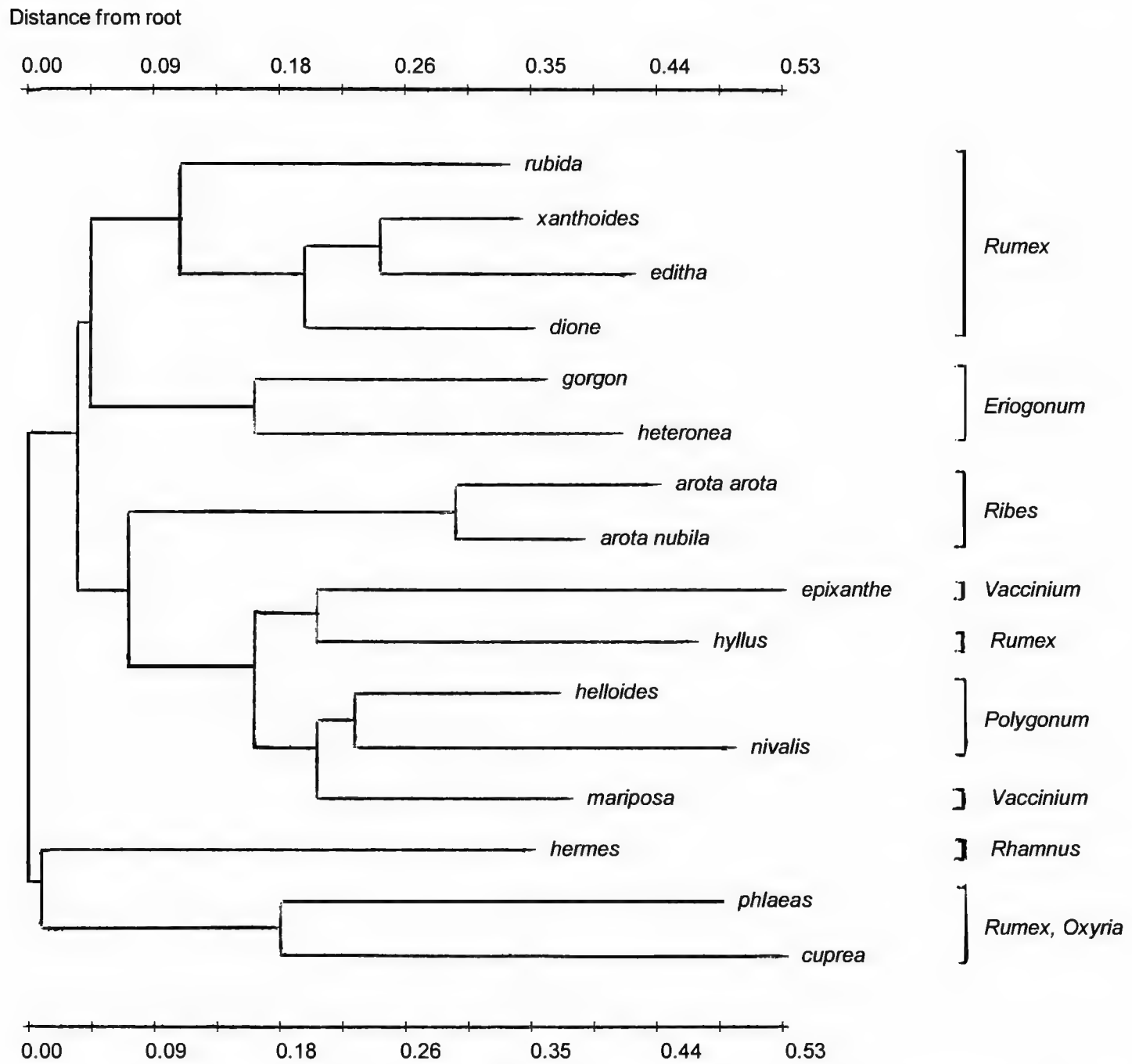


Figure 2. Distance Wagner tree of 16 North American coppers using Cavalli-Sforza & Edwards arc distances. Cophenetic correlation 0.912; percent standard deviation 13.159. Total length of tree = 4.537. Host plants in right margin.

genera. Allozyme differentiation implies that these subgenera are perhaps compatible with genera. Certain copper taxa are absent from the analysis. The addition of *Lycaena ferrisi* K Johnson & Balogh, *L. dorcas* Kirby, *L. cuprea snowi* (W. H. Edwards), and *L. (lophanus) pyrrhias*, as well as larger sample sizes, may improve the trees and disclose further relationships.

Miller & Brown (1979) pointed out the primitive position of *Lycaena phlaeas* and *L. cuprea* relative to other North American taxa. The ancestral position of these species is supported by our allozyme phylogenies. Several subspecies of *L. phlaeas* and many *L. cuprea*-like species occur throughout Eurasia (Henriksen & Kreutzer 1982, Higgins & Riley 1983, Korshunov & Gorbunov 1995, Tusov 2000, Gorbunov 2001). With extant relatives in the Palaearctic, it is most likely that the ancestors of both *L. phlaeas* and *L. cuprea* originated in the Palaearctic.

In our study the population of *Lycaena phlaeas* sampled is from eastern North America. Klots (1951) noted that eastern subspecies *L. phlaeas americana* Harris, corrected to *L. phlaeas hypophlaeas* (Boisduval) by Emmel & Pratt (1998), is

morphologically similar to European *L. phlaeas*. Opler and Krizek (1984) suggested that *hypophlaeas* is adventive and was most likely introduced into North America from Scandinavia during the American Colonial period (17th–18th century). An alternative hypothesis is that eastern populations of *hypophlaeas* existed endemically in the high elevations of the White Mountains in New England and expanded their range with the introduction of *Rumex acetosella*. An expansion of this sort has been observed with alpine populations of *L. cuprea* and *L. editha*. Both of these species have broadened their range with the introduction of *Rumex acetosella* into western North America (Emmel & Pratt, personal observation). Also high altitude California *L. phlaeas* from 12,000 feet elevation can be experimentally reared on *Rumex crispus* at 800 feet elevation (and lower), suggesting that the species has the ability to rapidly adapt to lowland conditions (Ballmer & Pratt 1989a). *Oxyria digyna* is the primary host plant of arctic-alpine *L. phlaeas* in North America (Shields and Montgomery 1966, Ferris 1974, Emmel & Pratt 1998). This plant occurs locally at high elevations on Mount Washington in New Hampshire; the possible existence of high altitude *L. phlaeas* colonies there and elsewhere in New England has not been studied.

Allozyme evidence suggests that each of the four species at the base of the tree (*L. phlaeas*, *L. cuprea*, *L. arota*, *L. hermes*) could belong to a separate genus or subgenus. The genetic distance between *L. phlaeas* and *L. cuprea* in the Nei Distance Tree (Fig. 1) is greater than the basal branch leading to all other subgenera. *Lycaena arota* and *L. hermes* from western North America form a cluster pair in the Nei Distance tree (Fig. 1), but fail to do so in the Distance Wagner Tree (Fig. 2). Thus these species seem to require a different grouping above the species level. If they were placed in separate subgenera, two (*L. arota*, *L. hermes*) would occupy monotypic subgenera. *Lycaena phlaeas* and *L. cuprea* on the other hand belong to a polytypic Holarctic subgenus. The current assignment of *L. cuprea* to the *Lycaena* may change once comparative molecular studies with Palearctic taxa have been completed. *Lycaena phlaeas*, the type species of *Lycaena*, will not change assignment.

In both trees (Figs. 1 and 2), the species in *Chalceria* segregate into two distinct subclusters consisting of *L. rubida*, *L. xanthoides*, *L. editha*, and *L. dione* in one group and *L. gorgon* and *L. heteronea* in the other. The branch length between them in the Nei Distance tree (Fig. 1) is virtually the same as branch lengths of other subgenera. A notable shift in host plants has accompanied this split. The first group uses hosts in the plant genus *Rumex*, while *L. gorgon* and *L. heteronea* have shifted to *Eriogonum*. Ballmer and Pratt (1989b) recognized distinct differences in the larvae of these two groups. If these two groups are eventually recognized as separate genera or subgenera, *Chalceria* must be applied to the former and a new genus must be erected for *L. gorgon* and *L. heteronea*.

In the Nei Distance tree (Fig. 1), the distance between *L. dione* and *L. xanthoides* is greater than that between *L. xanthoides* and *L. editha*. This is consistent with the notion that *L. dione* is a distinct species and supports the recent elevation by Opler and Malikul (1992). Whether *L. xanthoides* and *L. editha* are fully separate species is a controversial subject (Scott 1980, Pratt et al. 1991). In this analysis *L. xanthoides* lies intermediate between *L. editha* and *L. dione*. Although the genetic distance between *L. xanthoides* and *L. editha* is relatively small, *L. editha* tentatively should retain full species status. The allozyme relationships of

this group are congruent with the phylogeny in our previous morphological study of the *L. editha* Complex (Pratt et al. 1991). It should be noted that our allozyme study analyzed only a single population of each species and did not sample intermediate *L. editha* $\times$ *L. xanthoides* populations in northern California. We also did not examine *L. ferrisi*, the purported oldest member of this group. These limitations make it difficult to offer a stronger statement about the species status of *L. editha*.

Most of the species within the subgenus *Epidemia* form a clear cluster with the surprising exception of *L. hyllus*, which is currently assigned to the subgenus *Hyllolycaena*. In the Nei Distance tree (Fig. 1), *L. hyllus* is more closely related to the other *Epidemia* species than is *L. epixanthe*. *Lycaena hyllus* and *L. epixanthe* branch together in the Distance Wagner tree (Fig. 2), implying an ancestral relationship. Comparing their phenotypes, this relationship hardly seems possible. It appears that *L. hyllus* is either a member of *Epidemia* or *L. epixanthe* is a member of *Hyllolycaena*. (Alternatively, *L. epixanthe* could represent a separate monotypic subgenus.) Egg morphology and larval chaetotaxy reveal a close relationship between *L. hyllus* and the *Epidemia* species (Wright, personal observation). Future analyses with the addition of *L. dorcas* may help determine the breadth of *Epidemia* and its potential inclusion of *L. hyllus*.

Diapause Changes.—The first branch in the Nei Distance tree (Fig. 1) demarcates a conspicuous split between the species pair *L. phlaeas* and *L. cuprea* and the remaining North American coppers. This branch is coincident with a significant biological modification in diapause. Both *L. phlaeas* and *L. cuprea* diapause as partially grown larvae, while all other North American coppers diapause in the egg stage, or more accurately as first instars within eggs (Scott 1981, Wright 1983, Pratt & Ballmer 1986). Coppers outside of North America principally diapause as partially grown larvae well beyond the first instar (Clark & Dickson 1971, Gibbs 1980, Henriksen & Kreutzer 1982, Higgins & Riley 1983). These observations suggest that the evolution of the North American species, excluding those with their closest relatives in the Palearctic (*L. phlaeas* and *L. cuprea*), involved a diapause change from partially grown larvae to first instar larvae within eggs.

Most species of this unique group of obligate egg-diapausers are univoltine. One curious exception is *L. hyllus*, which has two broods. Progeny of the first brood of *L. hyllus* develop directly without diapause while the second brood in late summer produces eggs whose first instars enter diapause (Opler & Krizek 1984). Thus the diapause stage of this species is ultimately the same as its North American relatives. The modification of voltinism in *L. hyllus* appears to be a response to habitat, climate, moisture, and host availability. The precise mechanism how this species controls diapause is unknown. It is not clear in which stage multibrooded lowland *L. helloides* diapauses, but we speculate that it too diapauses within eggs like its congeners. This species is univoltine at high altitude where Scott (1986) reported egg hibernation. High altitude California *L. helloides* (> 6000 feet) when reared for three generations without diapause near sea level, entered diapause in late fall within eggs (Pratt, personal observation).

Host Plant Shifts.—It is likely that the original host plant of the North American coppers was *Rumex* or a closely related member of the Polygonaceae. Supporting this conclusion is the observation that coppers worldwide use Polygonaceae spe-

cies almost exclusively. The only continent where coppers venture onto hosts outside of the Polygonaceae is North America. Since North American coppers (excluding subgenus *Lycaena*) are more derived than their Palearctic counterparts, host shifts that occurred on this continent were most likely from Polygonaceae to another plant family. Also each North American subgenus with more than one species contains at least one species that feeds on either *Rumex* or *Polygonum* (Ballmer & Pratt 1989b).

The major host shifts of the North American coppers align with the major branches in the allozyme phylogenies. The first branching stem (subgenus *Lycaena*) in the Distance Wagner Tree (Fig. 2) did not switch hosts, but the following divergence (*L. hermes*) saw a host shift to the plant *Rhamnus crocea* Nuttall in Torrey and Gray (Rhamnaceae). The branching stem of the *Chalceria* did not involve a host shift, but within the subgenus there occurred a split leading to the closely allied pair, *L. gorgon* and *L. heteronea*, which shifted onto *Eriogonum*. Although *Eriogonum* belongs to the Polygonaceae family, the ability to feed on this plant genus may be considered a unique host shift. *Rumex* feeding species of *Chalceria* (*L. rubida*, *L. xanthoides*, *L. editha*, and *L. dione*) will not feed on *Eriogonum* in the lab, and in similar fashion *L. heteronea* and *L. gorgon* larvae will not feed on *Rumex*. The *Rumex* feeding species of *Chalceria* can readily switch between *Rumex* and *Polygonum* (Pratt, personal observation). These observations suggest that the shift to *Eriogonum* is an actual host shift and not easily reversible.

The species diversity of the *Eriogonum* feeders may be greater than presently appreciated. The lineage involving *L. heteronea* may contain two or more species. On the eastern slopes of the Sierra Nevada in western North America occur two sympatric populations of *L. heteronea*, one using *Eriogonum umbellatum* Torrey and the other *Eriogonum nudum* Douglas ex Benth. Adults and larvae of these two populations differ morphologically and suggest that two species coexist (Pratt et al. 1991). Samples of these populations were not included in this analysis.

The next major divergence in the Distance Wagner Tree (Fig. 2) splits the subgenera *Tharsalea* and *Epidemia*. *Tharsalea* is represented by a single species, which has shifted to exclusive use of *Ribes* (Glossulariaceae). In the subgenus *Epidemia* three species feed on either *Rumex* or *Polygonum* (Polygonaceae), but two species have shifted to *Vaccinium* (Ericaceae) (Wright 1983, Pratt & Ballmer 1986, Scott 1986). It appears that these host shifts, unlike the shift to *Eriogonum*, occurred independently since the two *Vaccinium* feeders are not closely related. The bog species *L. epixanthe* is more closely allied to *L. hyllus*, while *L. mariposa* is more closely related to *L. helloides*. We note with interest that host shifts to plants in Ericaceae have also occurred independently in the polyommata genera *Agriades*, *Lycaeides*, and *Vacciniina*, especially in species adapted to the bog-like habitats (Scott 1986, Emmel & Emmel 1998). *Lycaena dorcas*, another bog/fen dweller in the *Epidemia*, has shifted to *Potentilla* in the Rosaceae.

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SYNONYMY OF *DASYMUTILLA SICHELIANA* (SAUSSURE) (HYMENOPTERA: MUTILLIDAE)¹

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Abstract.—*Dasymutilla sicheliana* (Saussure) and *D. thera* (Cameron) have been known from females only, and were synonymized by Mickel in 1965. *Dasymutilla intermixta* Mickel and *D. thalia* (Cameron) have been known from males only. Examination of the holotypes and long series of specimens of both has shown these males to be the same species. Pitfall trap collections of both males and females at the Leslie Canyon National Wildlife Refuge near Douglas, Arizona, as well as collection data from specimens collected in both the United States and Mexico, have led to the conclusion that these are male and female of the same species. The name *D. sicheliana* has precedence. A complete synonymy is included.

Key Words.—Insecta, Hymenoptera, Mutillidae, *Dasymutilla sicheliana*, *Dasymutilla intermixta*, *Dasymutilla thalia*, synonymy.

Dasymutilla sicheliana was first described as *Mutilla sicheliana* by Saussure (1867). Saussure made his description on the basis of five female specimens, all from Mexico (two from Cordilliere and three from Tehuacan), and noted three different variations. Mickel examined Saussure's material in 1931 (unpublished notes) and designated a lectotype. That specimen is in the Geneva Museum, as are Saussure's other specimens.

Sphaerophthalma (sic.) *prunotincta* was described as a new species by Cockerell (1895) on the basis of a female found in Guanajuato, Mexico, by Dr. A. Duges. Although Cockerell made comparisons to several other species in his description, there was no reference made to *M. sicheliana*. After examination of Duges' type specimen, André (1898) wrote that *S. prunotincta* was a synonym of *M. sicheliana*. The type specimen for *S. prunotincta* has since been lost (Mickel 1928, 1965).

Sphaerophthalma (sic.) *thera* was described as a new species by Cameron (1895) on the basis of a female found in Milpas, Mexico, by Forrer. That type was examined by Mickel and found to be a synonym for *D. sicheliana* (1965). The holotype of *S. thera* is in the British Museum. *Mutilla gynaecologica* is listed as a new name for *S. thera* by Dalle Torre (1897).

The type specimens of *M. sicheliana* and *S. thera* were examined by DGM and found to be in agreement with Mickel. *Dasymutilla sicheliana* has been previously known only from the female, with its distribution being Arizona and Mexico.

Dasymutilla intermixta was described by Mickel (1928). The holotype for this species is in the University of Minnesota collection, and has been examined by

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DGM. It has been known only from the male, with its distribution being Arizona and New Mexico.

Sphaerophthalma (sic.) *thalia* was described by Cameron (1895) on the basis of two male specimens found in Guerrero, Mexico by H. H. Smith. The holotype is in the British Museum, and has been examined by DGM. It has been known only from the male, with its distribution being listed as Mexico.

MATERIALS AND METHODS

Beginning in 2000, U. S. Fish & Wildlife personnel (WRR) collected mutillids coincidentally with targeted reptiles and amphibians being live-trapped as part of a population dynamics study. The collections were made at Leslie Canyon National Wildlife Refuge in Cochise County, Arizona; Township 21 South, Range 28 East, Section 20 (Lat: 31°35.330' Long: 109°30.500'). Trap arrays were located at an elevation of 1419 m in various microhabitats within the canyon's riparian corridor. Each array consisted of pitfall traps (19-liter capacity buckets buried in the ground to the rim) at the end of 7.6 m sections of tan-painted, metal drift fences 36 cm high having 2-compartmental funnel traps located at the center of the fence. The funnel traps were boxes 1.2 m long by 0.6 m wide, and 0.3 m high constructed of 2.3 mm (1/8") hardware cloth separated longitudinally by a piece of plywood such that they functioned as two parallel traps. Funnels with 5 cm entrance holes led into these traps from each end. Funnels and pitfall traps were shaded from the sun with plywood coverings, and plywood bucket trap covers were elevated approximately 4 cm from ground level to provide access to reptiles, amphibians, and invertebrates. The plywood covers made it impossible for flying invertebrates to view the contents of the pitfall traps, and additionally made it virtually impossible for flying invertebrates to exit the traps once inside. About 5 cm of loose soil served as a substrate in the pitfall and funnel traps. In 2000, four trap arrays were operated from 5 April through 7 December. In 2001, eight trap arrays were in operation from 29 March through 6 December. Traps were checked approximately every other day to remove and record the vertebrates and invertebrates that were captured. All mutillids (Hymenoptera: Mutillidae) were collected, pinned, and shipped to Clemson University (DGM) for identification.

On 19 June 2000 one of the pitfall traps contained a single female of *D. sicheliana* and a single male of *D. intermixta*. On 20 June 2001 one of the pitfall traps contained a single female of *D. sicheliana* and eight males of *D. intermixta*. On 2 July 2001 one of the pitfall traps contained a single female of *D. sicheliana* and a single male of *D. intermixta*. All collections were by WRR, and no other mutillid specimens were collected in those traps on those dates.

Material Examined.—In addition to the type specimens mentioned above, the following material has been examined by DGM (all are females of *D. sicheliana* and males of *D. intermixta* and *D. thalia*): USA. ARIZONA. COCHISE Co.: Mouth of Carr Canyon, Huachuca Mts., 10 Aug 1940, C. D. Michener, 1 ♀; Garden Canyon, Huachuca Mts., 1954, W. H. Mann, 1 ♀ (homotype, *M. sicheliana*); Cottonwood Cañon, Peloncillo Mts., 25 Sep 1958, D. S. Creighton, 1 ♀; Portal, 8 Sep 1959, H. E. Evans, 1 ♂; Skeleton Canyon, 24 Aug 1962, P. Weens, 1 ♂ (homotype, *D. intermixta*); Carr Canyon, Huachuca Mts., 20 Jul 1969, G. H. & D. E. Nelson, 1 ♀ (homotype, *S. thera*); Miller Canyon, Huachuca Mts., 3 Apr 1973, R. F. Sternitzky, 1 ♀; Miller Canyon, Huachuca Mts., 21 Jun 1974, E. R. Hoebeke, 1 ♂; Chiricahua Mts., 9 Aug 1974, G. H. Nelson, 1 ♂ (homotype, *D. intermixta*); Portal, 12 Aug 1974, H. & M. Townes, 2 ♂; Portal, 13 Aug 1974, H. & M. Townes, 1 ♂; Portal, 30 Aug

1975, J. D. Pinto, 1 ♀; Ash Canyon, Huachuca Mts., 17 Aug 1980, S. Frommer, 1 ♂; 18.5 mi SE Willcox, 31 Aug 1980, McGinley & Woodley, 1 ♂ (homotype, *D. intermixta*); Portal, 19 Aug 1987, H. & M. Townes, 2 ♂; Portal, 23 Aug 1987, H. & M. Townes, 2 ♂; Portal, 1 Sep 1987, H. & M. Townes, 1 ♂; Leslie Canyon NWR, 2000, W. R. Radke, 7 Apr (1 ♀), 19 Apr (1 ♀), 22 May (1 ♀), 5 Jun (3 ♀), 7 Jun (1 ♀), 12 Jun (2 ♀), 14 Jun (1 ♀), 16 Jun (1 ♀), 19 Jun (1 ♀), 19 Jun (1 ♀ and 1 ♂ taken together), 2 Jul (1 ♀), 14 Aug (1 ♀), 14 Sep (1 ♀), 20 Sep (2 ♀), 27 Sep (1 ♀); Leslie Canyon NWR, 2001, W. R. Radke, 9 May (1 ♀), 11 May (1 ♀), 25 May (1 ♀), 11 Jun (1 ♀), 21 Jun (1 ♀ and 8 ♂ taken together), 2 Jul (1 ♀ and 1 ♂ taken together). PIMA Co.: Santa Rita Mts., 1 Aug 1941, R. H. Beamer, 1 ♂ (homotype, *D. intermixta*); Molino Basin, Catalina Mts., 30 Jul 1958, R. M. Bohart, 1 ♀; Vail, 11 May 1965, Johnson, 1 ♀; Florida Canyon, 2 Jul 1967, J. E. Heppner, 1 ♀ (homotype, *S. thera*); 4 mi W Box Canyon, 25 Aug 1977, R. W. & R. M. Brooks, 1 ♂; Santa Rita Exper. Range, 3 Aug 1986, D. L. Gustafson, 1 ♂. SANTA CRUZ Co.: 12 mi E Nogales, 14 Sep 1966, R. W. Thorp, 1 ♂; Sycamore Canyon, Atascosa Mts., 14 Jun 1968, Flint & Menke, 1 ♂. NEW MEXICO. CHAVES Co.: Bitter Lake NWR, 20 Jul 1998, G. L. Warrick, 1 ♂. HIDALGO Co.: Antelope Pass, 17–21 Aug 1992, B. Tomberlin, 1 ♀. COSTA RICA. GUANACASTE. S. Rosa Park, 12 Feb 1978, D. H. Janzen, 1 ♂; S. Rosa Park, 11 Mar 1978, D. H. Janzen, 2 ♂. MEXICO. AGUACALIEN-TAS. 6 mi E Calvillo, 11 Jul 1983, Kovarik, Harrison & Schaffner, 1 ♀ (homotype, *S. thera*). CHIA-PAS. 3 mi NW Petlalcingo, Pueblo, 2 Apr 1962, L. A. Stange, 1 ♀. CHIHUAHUA. Morelos, Cuernavaca, Dec 1944, N. L. H. Krauss, 1 ♀ (homotype, *M. sicheliana*); Santo Nino, 26 Jul 1968, T. A. Sears, R. C. Gardner & C. S. Glasner, 1 ♀; Santo Nino, 10 Aug 1968, T. A. Sears, R. C. Gardner & C. S. Glasner, 1 ♀. COLIMA. Manzanillo, 1–2 Aug 1965, H. E. Evans, 1 ♂ (homotype, *S. thalia*). GUERRERO. Zumpango, 22 Jul 1963, F. D. Parker & L. A. Stange, 1 ♂. JALISCO. Plan de Barrancas, 24 Mar 1962, F. D. Parker, 1 ♀/9 ♂; Plan de Barrancas, 24 Mar 1962, L. A. Stange, 2 ♀/2 ♂; 8 mi SE Plan de Barrancas, 8 Jul 1963, F. D. Parker & L. A. Stange, 1 ♂; 14 mi S Guadalajara, 11 Aug 1970, R. L. Villegas, 1 ♂; Teocaltiche, 26 Aug 1979, B. Villegas, 1 ♀; Chamela Biol. Stn., 16–20 Jul 1989, R. W. Brooks, 1 ♂. NAYARIT. 24 mi S Tepic, 7 Jul 1963, F. D. Parker & L. A. Stange, 1 ♀. OAXACA. 10 mi N Miltepec, 31 Jul 1972, ME-66, R. R. & M. E. Murray, 1 ♀ (homotype, *M. sicheliana*). SINALOA. 8 mi N Elota, 18 Mar 1962, F. D. Parker, 1 ♂; Chupaderos, 15 May 1962, F. D. Parker & L. A. Stange, 2 ♂; 8 mi S Elota, 19 May 1962, F. D. Parker, 1 ♀; 8 mi SE Elota, 19 May 1962, F. D. Parker, 2 ♀/1 ♂; 8 mi SE Elota, 19 May 1962, L. A. Stange, 1 ♀; 8 mi S Elota, 2 Jul 1963, F. D. Parker & L. A. Stange, 1 ♀; Chupaderos, 3 Jul 1963, F. D. Parker & L. A. Stange, 1 ♀; 8 mi S Elota, 26 Aug 1963, F. D. Parker & L. A. Stange, 2 ♀; Rio Choix, 19 Jul 1968, Sears, Gardner & Glaser, 1 ♂; 4 mi NW Choix, Arroyo del Saucillo, 12 Aug 1968, Sears, Gardner & Glaser, 1 ♂; Magistral, 18 Aug 1985, G. Ekis, 2 ♂; Santa Ana, 2 Aug 1985, G. Ekis, 1 ♂. SONORA. La Aduana, 22 May 1962, F. D. Parker & L. A. Stange, 2 ♂; Alamos, 7 Sep 1977, R. W. Brooks, 1 ♂; Santa Ana R., 4 Aug 1985, G. Ekis, 2 ♂; 108km W Hermosillo, 16 Aug 1991, R. L. Minkley, 1 ♂. ZACATECAS. Rio Grande, 19 Aug 1979, R. L. Villegas, 1 ♂.

DISCUSSION

The color of the pubescence is a variable characteristic that is often used in mutillid species descriptions. While color is a useful character, it can be misleading where series are limited or when pubescence is worn off in older specimens. Mickel (1931, unpublished notes) confirmed that Saussure's three variations of *D. sicheliana*, which were based on color differences, are the same species, as well as the fact that *S. thera* is a synonym of *D. sicheliana* (1965). We are in agreement with those assessments.

The holotypes of *D. intermixta* and *S. thalia* have been examined and found to be identical except for slight variations in color of pubescence, and collection locality. Previously known specimens of *S. thalia* were all from Mexico, whereas previously known specimens of *D. intermixta* were all from Arizona. Examination of long series of specimens from both Mexico and the United States has shown color variation in specimens from both countries to be similar. There is no justification for recognition of the two as separate species.

Positive sex correlation can be established by collection of mating pairs or

collection of both sexes from host cells. However, hosts are known for only a small percentage of mutillid species, and it is very difficult to obtain mating pairs in nature as mating may be very rapid (Manley & Deyrup 1989). In earlier studies, Manley (1999a, b) has shown the practice of caging females to be an alternative and reliable means of establishing sex correlation in mutillids.

In this study there was no deliberate attempt to cage females. However, on three different occasions, females of *D. sicheliana* that were collected in pitfall traps attracted males of *D. intermixta* into the traps. The fact that in all three instances no other mutillids (females or males) were in the traps is very strong evidence that these are male and female of the same species. And, although it is not known whether Parker and Stange (1962, see Material Examined) found other species of mutillids at the same time, the fact that they found females of *D. sicheliana* in conjunction with males of *D. intermixta* at three different times lends support to this conclusion. All specimens examined in this study, with the exception of the type specimens, are in the collections of UC Davis and the author (DGM). Since the name *D. sicheliana* has precedence, that name shall stand. A synonymy for the species follows.

DASYMUTILLA SICHELIANA (SAUSSURE)

Mutilla sicheliana Saussure, 1868: 360. ♀

Sphaerophthalma prunotincta Cockerell, 1895: 60. ♀

Sphaerophthalma thera Cameron, 1895: 358. ♀ Preocc. In *Mutilla* by Smith, 1864.

Sphaerophthalma thalia Cameron, 1895: 372. NEW SYNONYM. ♂

Mutilla gynaecologica Dalla Torre, 1897: 45. ♀ N. name.

Dasymutilla intermixta Mickel, 1928: 256. NEW SYNONYM. ♂

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**HIGH TEMPERATURE RESPONSES IN TWO EXOTIC
LEAFCUTTING BEE SPECIES: *MEGACHILE APICALIS*
AND *M. ROTUNDATA*
(HYMENOPTERA: MEGACHILIDAE)**

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Abstract.—Two exotic leafcutting bee species, *Megachile apicalis* and *M. rotundata*, have established feral populations in the Central Valley of California. Females of both species nest in exposed, oak savannah habitats where in the summer months ambient temperatures regularly exceed 40.0° C. Sympatric native bee species in the Central Valley of California are found most abundantly in insulated riparian zones where relatively cool temperatures and high humidities prevail. We examined physiological responses of *M. apicalis* and *M. rotundata* to high temperatures in the laboratory. Prepupal stage bees (in cocoons) were subjected to nine, three-hour temperature treatments of approximately 2.5° increments from 35.0° to 55.0° C. *Megachile apicalis* had significantly lower levels of the stress protein “heat-shock 70” (hsp70) than *M. rotundata* at all but the three highest temperature treatments. In a separate trial, hsp70 levels did not differ between species after four days of acclimation at 25.0° C but diverged significantly after a three-hour heat-shock treatment comparable to the ones described above. Both species survived temperatures up to 47.5° C, but began to differentiate around 50.0° C with *M. apicalis* demonstrating higher survivorship at or above that temperature. These findings indicate both species are highly thermotolerant, but agree with field data indicating that *M. apicalis* is more tolerant of high temperatures than *M. rotundata*.

Key Words.—Insecta, heat-shock or stress protein, invasive species, survivorship, thermotolerance.

Three exotic leafcutting bee species in the subgenus *Eutricharaea* have established feral populations in the U.S.A. during the 1900s: *Megachile apicalis* Spinola, *M. rotundata* (Fabricius) and *M. concinna* Smith (Cane 2002). These Old World species now appear to be establishing different geographic ranges within the western U.S.A. *Megachile concinna* is a southerly-distributed species in California that extends into the southwestern states of Arizona and Oklahoma. *Megachile rotundata*, the alfalfa leafcutting bee, has extended its range from northern California into the Pacific Northwest (U.S.A.) while *M. apicalis* reaches its highest densities within the Central Valley of California but also extends into southern California and the northern states of Oregon and Washington (Thorp et al. 1992, Thorp 1996, Frankie et al. 1998, Thorp et al. 2000, Barthell et al. 2002). Both species are multivoltine in California, flying from May into October with *M. rotundata* initiating nesting earlier in the season but with *M. apicalis* dominating in late summer and autumn (Stephen 1987, Thorp et al. 1992).

In an earlier study, both *M. apicalis* and *M. rotundata* were found to nest in

open, exposed habitats such as oak savannah, a pattern that contrasts with the nesting densities of sympatric native species which are restricted to riparian and marsh habitats (Barthell et al. 1998). Temperature and humidity patterns differ markedly between these habitats, with the more insulated marsh and riparian habitats having lower maximum and higher minimum biweekly temperatures (Barthell 1992). In the Central Valley of California the highly invasive *M. apicalis* nests in exposed microhabitats with ambient temperatures that can exceed 50.0° C. Nonetheless, over 60.0% of its offspring survive these conditions (Barthell et al. 1998). The tendency for *M. apicalis* to nest in and survive such thermal extremes, coupled with its more southerly distribution in California, suggest that it has higher thermotolerance than *M. rotundata*.

We examined responses to high temperature by *M. apicalis* and *M. rotundata* to test the hypothesis that these species have differing thermotolerances in accordance with their current distributions in California. We did so through measurement of stress protein levels (in the heat-shock 70 family of proteins) and survivorship. Heat-shock proteins are a well-documented indicator of stress in other organisms and heat-shock 70 proteins show a specific role in response to heat-induced stress (Feder & Hofmann 1999). No previous studies have measured either of these factors comparatively among solitary bees. Although both species appear to resist high temperatures well, we predicted that *M. apicalis* would have a more heat-tolerant thermal profile than *M. rotundata*.

MATERIALS AND METHODS

Origin of Live Material.—*Megachile rotundata* specimens were obtained as prepupae within brood cells from International Pollination Systems (IPS) in Manitoba, Canada. *Megachile apicalis* prepupae originated from field collections made at the Cosumnes River Preserve in the Central Valley of California. Sampling units consisted of 0.65 cm diameter $\times$ 15.5 cm length straws inserted into pre-drilled holes in 9.0 $\times$ 9.0 $\times$ 16.0 cm wooden blocks. These nests were set out in the field on 17 July and picked up on 10 August, 2000, to obtain second generation larvae that would diapause later in the season. Except during transport, brood cells of both species were kept in cold storage at their respective origin points but were refrigerated together under the same conditions (ca. 0.0°–15.0° C) for ca. three weeks (beginning on 14 February, 2001) before using the experimental protocol described below.

A second set of cells was collected the following year (2001) on 9 December from wooden trap-nest sampling units that were set out in the field on 9 August. All extracted straws (taped to 21.5 $\times$ 28.5 cm sheets of paper) collected from Cosumnes Preserve with brood cells of *M. apicalis* were x-rayed using a Hewlett-Packard 43805N Faxitron machine. Nests were exposed (3mA, 30 kVp) on Kodak XTL-2 film, allowing detection and removal of most parasitized cells used during Trials 1 and 2 described below. *Megachile apicalis* cells harvested from 0.50 cm diameter trap-nests in 2001 were used in Trial 3 (below) as well as new *M. rotundata* cells harvested during 2001 by IPS. Brood cells of both species were stored together for ca. 11 weeks (beginning on 8 January, 2002) at 5.0° C before the trial.

Trial 1: Tolerance to High Temperatures.—Brood cells (containing prepupae) of both *M. apicalis* and *M. rotundata* were removed from refrigeration and placed

at room temperature (ca. 20.0–25.0° C) on 8 March 2001. Cells were separated by species and treatment and then stored in petri dishes until heat-shock treatments began on 12 March. Approximately 110 brood cells were placed into each dish and color-coded with small, light streaks of Liquid Paper® (The Gillette Company, Boston, Massachusetts) to facilitate species identification.

Brood cells of both species were randomly mixed onto a single styrofoam plate for each temperature treatment and placed into a Little Giant® 9200 still air incubator (Miller Mfg., St. Paul, Minnesota) for three hours (11:00–14:00). Nine simultaneous temperature treatments were used, including approximately 2.5° increments from 35.0° to 55.0° C. (The exception was the 50.0° C treatment which actually received a 49.0° C exposure.) All plates with brood cells were simultaneously removed and allowed to cool at room temperature for 60 min after the three-hour trial. Twenty-five cells were randomly removed from each plate and immediately frozen at –80.0° C. The remaining cells were sorted by treatment and species into plastic petri dishes and incubated at 30.0° C. We report survivorship as well as both qualitative (SDS-PAGE) and quantitative (ELISA) measurements of stress protein levels (as described below) for this trial. Survivorship and protein levels were analyzed for significant differences between species using a Wilcoxon signed-rank test and a two-factor ANOVA, respectively.

Trial 2: Survivorship at 50.0° C.—To better differentiate the survivorship between species (the 49.0° C described above showed only incipient mortality), we subsequently exposed additional prepupae of *M. apicalis* and *M. rotundata* to 50.0° C (100 brood cells per species) on 7 May 2001. The same experimental conditions as described above were used and the experiment began at approximately the same time of day. To avoid parasitoid contamination (see below), the treated brood cells were placed in petri dishes which had been coated (inside bottom and lid) with a sticky layer of Tanglefoot® (Grand Rapids, Michigan). The brood cells were spaced equally across the bottom of each dish and then allowed to emerge in the 30.0° C incubator as before. We censused survivorship in this trial without examining hsp70 levels.

Trial 3: Stress Proteins in Acclimated vs Heat-shocked Larvae.—We observed unexpectedly high levels of hsp70 during Trial 1, even at all lower temperatures (including 35.0° C). To determine whether baseline levels of hsp70 in *M. apicalis* and *M. rotundata* were equivalent before heat-shock, we exposed groups of 25 prepupae of each species to simultaneous three-hour treatments of 25.0° and 35.0° C after a four-day acclimation period at 25.0° C. The work was conducted a year after Trial 1 (25 March, 2002) with prepupae collected during 2001 (see Materials and Methods). Otherwise, the same protocol as Trial 1 (except cold-storage temperature) was used to compare treatment and species differences in stress protein levels. A *t*-test was used to test for significant differences in protein levels between species.

Censusing Survivorship (Trials 1 & 2).—All brood cells (in their respective petri dishes) were removed for examination (including unemerged cocoons) four weeks after Trial 1. For Trial 2, cells were allowed to incubate approximately six weeks at 30.0° C before being removed from the incubator. These incubation periods meet or exceed those recommended for emergence of *M. rotundata* from Canada at 30.0° C (Peterson et al. 1992). After incubation, each cocoon/specimen

was scored as being in one of four categories as indicated below (samples were kept refrigerated between successive examination sessions to slow decay).

Parasitoids encountered during the study included a *Pteromalus* sp. that originated from *M. rotundata* cells. Among *M. apicalis* brood cells, the parasitoids included a wasp species in the family Leucospidae and numerous individuals of a *Melittobia* species. Some *Melittobia* (apparently not detected earlier by x-rays) parasitized brood cells of both bee species in all petri dishes (they were small enough to disperse under the petri dish lids to all other dishes). This required assessing survivorship according to four categories, only three of which were required for Trial 2 since no parasitoids emerged from those study specimens. The categories include the following: 1) *Emergent adults* (scored as surviving) that had chewed through and departed from their cocoons; 2) *Parasitized pre-adults* (scored as surviving) that included any unemerged bees in either the prepupal or pupal stage with feeding damage by and development of parasitoid larvae; 3) *Non-parasitized prepupae* (scored as dead) that included prepupae without obvious feeding damage by parasitoids. Any parasitoid larvae associated with these prepupae were small and morbid in appearance, indicating they had arrived at the prepupae after it died from heat exposure; 4) *Previously dead larvae* (excluded from analyses) that included unemerged larvae without parasitoid damage but that had obviously been dead prior to the heat treatment as evidenced by their hardened and/or darkened state (some of these had been killed by chalkbrood infection).

Although larval mortality appears to differ between male and female *M. rotundata* (e.g., Undurraga & Stephen 1980), we could not consistently record this variable because of parasitoid damage to specimens (see categories 2 and 3, above). However, since study specimens were randomly selected for heat treatments, we presumably avoided a sex-bias in our study.

Detection and Measurement of Hsp70 (Trials 1 & 3).—Five prepupal head capsules were used per homogenate in each trial to ensure adequate amounts of soluble protein for analyses. (In Trial 3 we used four heads in one sample of *M. apicalis*, but the protein concentration was still sufficient for analysis.) These were homogenized in 10 mM phosphate buffered saline (PBS) at pH 7.6, with 2 mM tosyl arginine methyl ester (TAME) and 0.2% sodium azide. After centrifugation ($16,000 \times g$ for 20 min), the protein content was determined by the Bradford assay (Bradford 1976).

We used one-dimensional SDS-PAGE (Laemmli 1970) to separate 80 μ g of total protein by molecular weight in Trial 1. Homogenate volumes were combined with sample reducing buffer (1:2 ratio) containing bromophenol blue (0.1%). These were denatured for 4 min at 95° C. Proteins were then separated on a minigel (Bio-Rad Laboratories, Hercules, California) at 20V for 8 h. The resulting proteins were then transferred (overnight) to nitrocellulose membranes at 90 mAmps in Tris-glycine-methanol (pH 8.6) buffer using a corresponding miniblott apparatus. Ponceau-S stain was then used to detect general proteins following the transfer (Sambrook et al. 1989). After washing with distilled water and blocking with 3% gelatin TBS, hsp70 family proteins were detected using a monoclonal antibody (1:1000 dilution) for bovine hsp70 (Sigma-Aldrich, St. Louis, Missouri) and an alkaline phosphatase-conjugated secondary antibody (1:3000 dilution).

Two replicate gels were run to confirm the observed banding patterns and to justify further analysis using a modified ELISA test (Yu et al. 1994).

Quantitative measurement of hsp70 using the ELISA test (Trials 1 and 3) involved coating wells of costar microplates (Bio-Rad Laboratories, Hercules, California) overnight with 2000 ng of soluble protein in a buffer of 0.01 M sodium carbonate and bicarbonate buffer (pH 9.6). Plate wells were then washed with PBST (10 mM PBS, 0.05% Tween 20) and then blocked with 1% PBST-BSA for one hour at 37.0° C. Plate wells were then washed (4 × PBST) and alkaline phosphatase-conjugated secondary antibodies were added (1:3000 dilution). After an hour of incubation (37.0° C), plate wells were washed again (6 × PBST) and 200 µl Bio-Rad detection solution was added to each well. After a 60 min incubation at 37.0° C, the optical density 405 nm for each well was recorded with a MR5000 EIA reader (Dynex Technology, Chantilly, Virginia). Each plate contained five bovine hsp70 standards (Sigma-Aldrich, St. Louis, Missouri) that were loaded in triplicate. Each of the three homogenates were also loaded onto the microplates in triplicate, and an average absorbance was calculated for each homogenate. Using the hsp70 standard curve (per microplate), we calculated hsp70 concentrations per homogenate which were used to calculate treatment means.

RESULTS

Trial 1: Tolerance to High Temperatures.—A single hsp70 isoform was detected by one-dimensional SDS-PAGE in Trial 1. We compared hsp70 family protein band intensities between species on nitrocellulose membranes taken from the SDS-PAGE procedure described above for Trial 1. Figure 1 shows a representative sample of these results. In general, except for the highest temperature (55.0° C), bands were detectable for *M. rotundata* at all heat exposures (Fig. 1a). A series of three relatively intense bands appears in the range of 40.0–45.0° C (lanes 3–5) with a decline in intensity thereafter. Overall, bands are fainter for *M. apicalis* with higher intensity around 45.0° C (Fig. 1b). A band was not detectable for this species at 55.0° C.

The ELISA results shown in Fig. 2 are consistent with the banding patterns described above and indicate interspecific differences. First, the two species had significantly different levels of hsp70 as indicated by a two-factor ANOVA ($F = 82.86$, $df = 1$, $P < 0.001$). Mean differences were significant between species for each treatment except the three highest temperature treatments (using Fisher PLSD mean separation tests). Peaks in hsp70 levels are apparent at 42.5° C (5.33 ng/µl) and 45.0° C (5.82 ng/µl) for *M. rotundata* and *M. apicalis*, respectively. A significant decline from the peak for *M. rotundata* first occurs at 47.5° C whereas *M. apicalis* does not decline significantly from its peak until 52.5° C.

Overall survivorship among the nine treatments was significantly different between *M. apicalis* and *M. rotundata* according to a Wilcoxon signed-rank test ($Z = -3.603$, $P < 0.01$). A slight decline in survivorship for both species is first noticeable at 49.0° C (Fig. 3). However, among the *M. apicalis* cells scored as surviving at that temperature, 73.2% (52 of 71) had emerged as adults while only 4.1% (3 of 73) of surviving *M. rotundata* had emerged from their cocoons. Of the brood cells exposed to the 52.5° and 55.0° C treatments, neither *M. rotundata* nor *M. apicalis* emerged from brood cells. However, 43.7% (31 of 71) and 15.9% (11 of 69) of *M. apicalis* larvae were scored as survivors (as evidenced by par-

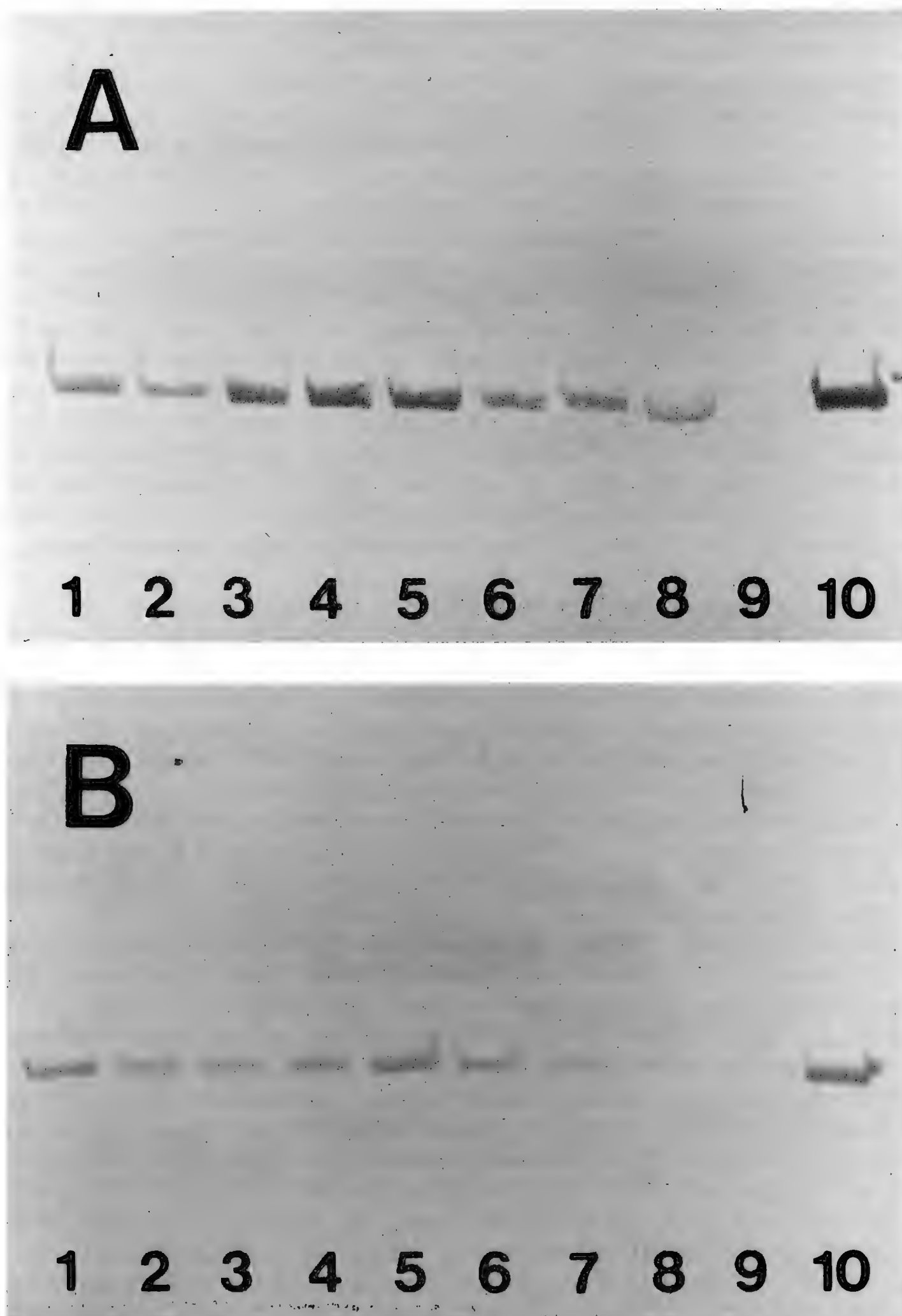


Figure 1. One-dimensional Western blot of hsp70 family proteins as detected with anti-bovine hsp70 antibodies. Each lane contained equal quantities of total protein derived from head capsule homogenates of *M. rotundata* (A) or *M. apicalis* (B). Lanes 1-9 represent ascending temperature treatments (degrees Celsius): 1 = 35.0, 2 = 37.5, 3 = 40.0, 4 = 42.5, 5 = 45.0, 6 = 47.5, 7 = 49.0, 8 = 52.5 and 9 = 55.0. Lane 10 = hsp70 control.

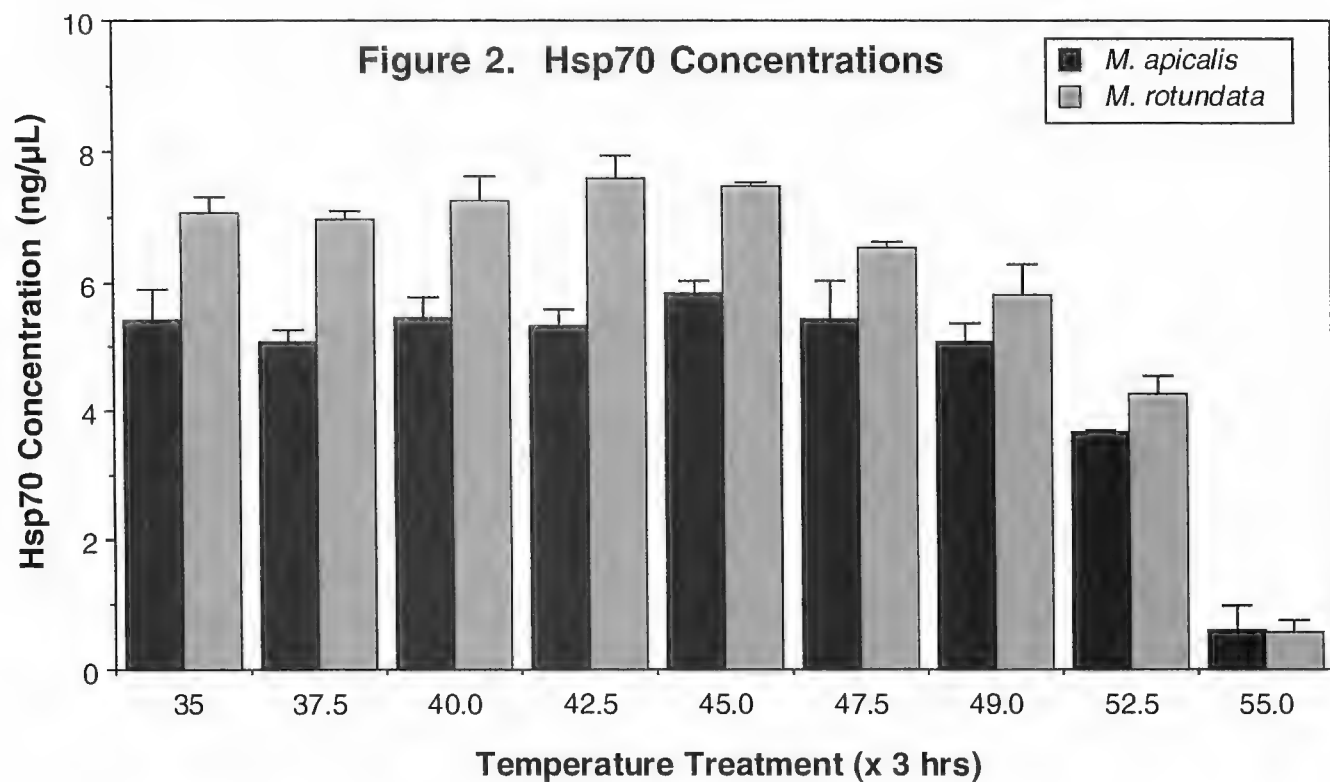


Figure 2. Mean (± 1 SE) concentrations of hsp70 (ng/ μ l) derived from head capsules of *Megachile apicalis* and *M. rotundata* for nine temperature treatments.

asitoid feeding activity) at these two temperatures, respectively. None of these had advanced beyond the prepupal stage. All cocoons showed evidence of parasitoid entry (small circular openings) and no pre-adult bees had survived parasitoid attack after the four-week incubation period. Teneral adults had apparently succumbed to dessication after parasitoid damage to the cocoon.

Trial 2: Survivorship at 50.0° C.—The 50.0° C treatment corroborated our ear-

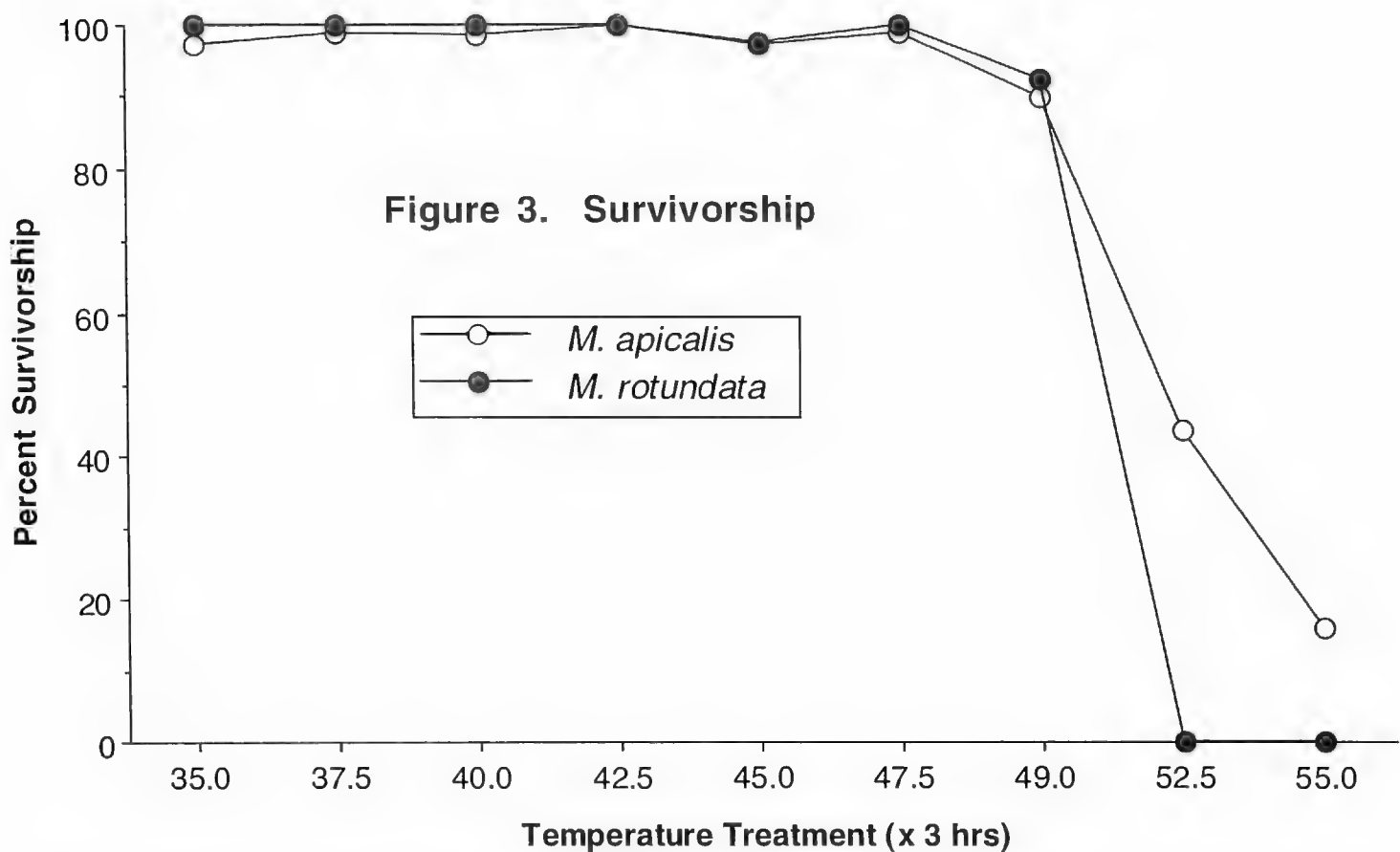


Figure 3. Percent prepupal survivorship of *M. apicalis* and *M. rotundata* compared at nine temperature regimes.

lier result that *M. apicalis* has higher survivorship at the highest temperature treatments in our study. Emergence of adult *Megachile apicalis* from brood cells after six weeks was 40.6% (39 of 96 viable brood cells) relative to 20.0% (18 of 90 viable cells) for *M. rotundata*. Dissection of non-emerged cocoons revealed that 68.8% (66 of 96) of *M. apicalis* brood cells exposed to 50.0° C either successfully emerged, died as teneral adults or advanced to the pupal stage. For *M. rotundata*, 32.2% (29 of 90) of prepupae advanced to the same stages. No parasitoid feeding activity was observed in any cells of either species during this trial. A number of bees that emerged from cocoons showed evidence of teratogenic effects, including at least 28.2% (11 of 39) of *M. apicalis* and 5.6% (1 of 18) of *M. rotundata*. Typically, these malformations related to appendages (e.g., missing or stunted wings and legs).

Trial 3: Stress Proteins in Acclimated vs Heat-shocked Larvae.—Using the same ELISA technique as described above, no significant difference in hsp70 levels was found between *M. apicalis* (5.25 ± 0.749 ng/ μ l) and *M. rotundata* (5.90 ± 1.067 ng/ μ l) when maintained at 25.0° C ($t = -0.503$, $df = 4$, $P = 0.32$). However, a significant difference in levels was recorded after the three-hour exposure to 35.0° C. *Megachile apicalis* contained substantially lower levels of hsp70 than *M. rotundata* (4.15 ± 0.543 vs 7.24 ± 0.481 ; $t = -4.269$, $df = 4$, $P < 0.01$).

DISCUSSION

Although both of our study species appear to tolerate high-temperature environments, the geographic range and nesting habits of *M. apicalis* suggest it has higher thermotolerance than *M. rotundata* (Thorp 1996, Barthell et al. 1998). Our study corroborates these observations with higher survivorship for *M. apicalis* exposed to 50.0° C (and above) while higher stress protein (hsp70) levels were measured in *M. rotundata* in response to elevated temperatures (except at 55.0° C where the most rapid mortality presumably occurred for both species). These differences are likely to be induced by heat-shock since we later failed to find a significant difference between species when samples received a four-day acclimation period at 25.0° C in Trial 3. (Hsp70 levels did, however, differ significantly after the three-hour exposure to 35.0° C.) These results therefore support the conclusion that the elevated levels of hsp70 recorded in *M. rotundata* were a result of temperature-induced stress.

It is unclear whether any species-specific developmental differences influenced our results in the experimental trials. *Megachile apicalis* and *M. rotundata* do have differing flight periods (Thorp et al. 1992) and the developmental sequence from diapausing prepupal to pupal stages just prior to adult emergence could affect hsp70 levels differentially between species. *Megachile rotundata* demonstrates variation among protein concentrations during this transition, for example, and hsp70 appears to be one of those that varies (Rank et al. 1982, 1989; Hranitz & Barthell in press). However, we exposed both study species (together) to at least a three-week cold storage period and we collected cells of *M. apicalis* later in the season (August) to obtain as many of the diapausing generation bees as possible (the same stage as the commercially-harvested *M. rotundata* used in the study).

The literature is replete with evidence that elevated hsp70 levels reflect stress

in organisms (Feder & Hofmann 1999). In insects this pattern has been observed in fruitfly larvae, *Drosophila melanogaster* (Meigen), when exposed to high temperatures in nature (Feder et al. 1997). Cold-shock stress also produces elevated levels of hsp70 in the flesh fly *Sarcophaga crassipalpis* Macquart (Joplin et al. 1990). In diapausing gypsy moths, *Lymantria dispar* L., an elevation in stress proteins occurs in response to both high and low temperatures (Yocum et al. 1991). Both bacterial infection and heat stress increase hsp70 production in honey bees (Severson et al. 1990, Gregorc & Bowen 1999). The significantly higher hsp70 levels we recorded in *M. rotundata* probably reflect lower heat tolerance in this species and is consistent with the northerly distribution of its feral populations in California. However, since the *M. rotundata* specimens used in our study originated from a commercial source in Canada we still await the opportunity to compare individuals of *M. apicalis* and *M. rotundata* sampled from sympatric populations in California.

Although no thermotolerance studies exist in the literature for *M. apicalis*, several such studies exist for the economically important *M. rotundata*. Whitfield and Richards (1992) demonstrated a slightly decreased developmental rate for later instar larvae of *M. rotundata* in the range of 32.0° to 35.0° C. Undurraga and Stephen (1980) found no survivorship of either prepupae or pupae during either brief or extended (as long as 3 h) exposures to 50.0° C, but with high survivorship at 45.0° C. The latter study shows lower survivorship at 50.0° C than in our study for *M. rotundata* (0.0 vs 20.0%). However, these differences could be explained by differing acclimation conditions between studies as well as larval developmental conditions in the original, pre-study environments; the importance of this latter point is emphasized in recent contributions by Kemp and Bosch (2000, 2001). Our criteria for assessing survivorship (based upon parasitoid feeding activity) differed from these other studies as well. Nonetheless, it is clear that *M. rotundata* is severely compromised (> 50.0% mortality) in the prepupal stage when exposed to 50.0° C for a three hour period or less.

Teratogenic effects were not specifically addressed in the mortality studies cited above, nor by Tepedino and Parker (1986), even though we observed them in both species after Trial 2. Such effects were not conspicuous among specimens that emerged from any of the temperature treatments conducted in Trial 1. Although prepupae used in Trial 2 came from the same source as those used in Trial 1 (and were maintained in cold storage), there is a possibility that bees in Trial 2 were somehow physiologically altered between trials. It may also be that other components of our experimental protocol (or these factors in combination with the treatment exposure) produced the effects we observed in Trial 2.

Although no comparative studies measuring survivorship and stress proteins among solitary bee species exist in the literature, such studies have been conducted for marine molluscs. Two blue mussel species, *Mytilus trossulus* Gould and *M. galloprovincialis* Lamarck (collected from northern and southern latitudes, respectively), for example, show significant differences in hsp levels under temperature stress (Hofmann & Somero 1996). *Mytilus trossulus* accumulates higher levels of hsp66 and hsp70 than *M. galloprovincialis* after acclimation to 13.0° C for eight weeks, evidence that the more cold-adapted *M. trossulus* experiences greater physiological stress at temperatures above their normally encountered temperature (ca. 10.0° C). In another study, Tomanek and Somero (1999) studied four

marine snails in the genus *Tegula* collected from sites along the Pacific coast of the U.S.A. One of these, *T. rugosa* (Adams), originated from a more southerly locale than the others (Baja California) and displayed higher onset, peak and inactivation temperatures for hsp70 expression relative to three temperate species collected near Pacific Grove, California. One of the three temperate species, *T. funebris* (Adams), lives in a broader range of habitats (mid- to low-intertidal zones) that can expose it to high air temperatures during low tide. It also has higher onset, peak and inactivation temperatures in comparison with the other two temperate species.

Our findings are consistent with aspects of the marine invertebrate studies cited above. *Megachile rotundata*, a more northerly-distributed species accumulates higher hsp70 levels than *M. apicalis* during heat-treatments in our study. The generally high levels of hsp70 in Trial 1 may have obscured the actual peaks as well as the onset and inactivation temperatures for both species. However, a significant decline from the observed peaks of hsp70 occurred at a lower temperature in *M. rotundata* than in *M. apicalis*, suggesting a higher inactivation temperature for the latter species. The unexpectedly high levels of hsp70 at lower temperatures (relative to acclimated individuals in Trial 3) may reflect a heat-shock response to rapid heating rates ($\geq 10^{\circ}\text{C}$ in < 10 min) used in Trial 1, a condition unlike larvae would experience in nature. Lutterschmidt and Hutchison (1997) caution about such confounding effects in studies of thermotolerance.

Thermotolerance in an invasive species may be an important indicator of the range that it will ultimately occupy in a newly invaded environment. Indeed, thermotolerance has been a key element in predicting the outcomes of other invasive Hymenoptera such as African honey bees (Taylor 1977). Although the original, Eurasian ranges of *M. rotundata* and *M. apicalis* are unclear from reports in the literature, these species are currently occupying ranges in the western USA that are in accord with the thermotolerance patterns recorded in our study. *Megachile apicalis* appears to be able to occupy a higher thermal niche relative to *M. rotundata*, but we still await comparisons with sympatric native species identified in previous studies (Barthell et al. 1998, Frankie et al. 1998). Such comparisons will allow us to determine if thermotolerance is a factor in the rapid range expansion observed for *M. apicalis* since its initial detection in southern California nearly two decades ago (Cooper 1984).

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**A NEW SPECIES OF *GLAUCINA* HULST FROM
WYOMING AND COLORADO, AND DESCRIPTION OF
THE FEMALE OF *G. NEPHOS* RINDGE
(LEPIDOPTERA: GEOMETRIDAE)**

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Abstract.—A new species in the geometrid moth genus *Glaucina* is described from Wyoming and Colorado. The previously unknown female of *Glaucina nephos* Rindge is described from Wyoming specimens.

Key Words.—Insecta Colorado, Geometridae, *Glaucina* n. sp., Insecta, Lepidoptera, Wyoming.

Ultraviolet light traps placed by the first author in the Sherman Hills east of Laramie, Wyoming in late June and early July 1999 yielded two males and two females of a large and virtually unmarked gray *Glaucina*. Comparison of these specimens with the imagines illustrated in Rindge's 1959 revision of the genus produced no matches. Subsequent dissections of a male and female with comparison to Rindge's plates again produced no matches. Photographs of the specimens and their genitalia were subsequently sent to Dr. Rindge at the American Museum of Natural History for his opinion. In a letter to Ferris dated 19 April 2001, he replied: "I agree that the *Glaucina* is an undescribed species; we have nothing to match it."

When Nordin then examined a backlog of unplaced specimens in his collection and unprepared material in his freezer, he found four specimens from Colorado and a few additional specimens from Albany Co., Wyoming. While Ferris was on extended travel in 2001, Nordin operated ultraviolet light traps in Albany Co. at sites where specimens had been taken previously. This effort generated the additional specimens included in the type series.

In addition to the new species, two other large *Glaucina*, *interruptaria* (Grote) and *nephos* Rindge, occur in Albany Co. The dark dorsal forewing markings of *G. nephos* immediately separate it from the new species. The new species is most easily confused with *G. interruptaria*. Fresh specimens of *G. interruptaria* have a distinct pattern of fine dark markings on the dorsal forewing that is absent in the new species. Worn specimens must be dissected to ascertain identity. Additional comments follow in the *Diagnosis and Discussion* section.

To permit easy comparison of species, the format of the ensuing descriptions is purposely modeled after the format used in the 1959 revision of *Glaucina* by Rindge. The new species is described from 51 males and 9 females from Wyoming and Colorado. It seems to have been missed previously because it flies early in the season when weather conditions are extremely variable, and before itinerant

collectors normally travel in the region. Additionally, it is localized and may have specialized habitat requirements.

GLAUCINA INCOGNITARIA FERRIS AND NORDIN, NEW SPECIES

(Figs. 1–5, 7–12)

Types.—Holotype, male (Figs. 1 and 2), Wyoming, Albany Co., T[ownship]15N R[ange]71 W S[ection]29, NE of Pole Mtn., south of Happy Jack Rd., 41°13.78' N 105°22.30' W, 2538 m, 23.vi.2001, leg: J. S. Nordin. Paratypes, 50 males and 9 females with data as follows (specimens leg: J. S. Nordin except as noted): WYOMING, Albany Co.: T12 N R72 W S24, 41°00.34' N 105°25.00' W, 2309 m, 2.vii.1999, 1f; T14 N R71 W S36, 41°08.19' N 105°17.54' W, 2355 m, 8.vii.1995, 1 m; T15 N R71 W S18, 41°15.82' N 105°23.64' W, 2500 m, 1–2.vii.1999, 2 m, 1f, leg; C. D. Ferris; T15 N R71 W S29, 41°13.78' N 105°22.30' W, 2538–2544 m, 24–25.vi.1999, 1f, leg; C. D. Ferris; 22.vi.2000, 4 m; 24.vi.2000, 1 m; 25.vi.2001, 14 m, 2f; 27.vi.2001, 2 m; 28.vi.2001, 8 m, 4f; 30.vi.2001, 9 m; 2.vii.01 4 m; T15 N R73 W S1, 41°17.89' N 105°31.50' W, 2277 m, 5.vii.1988, 1 m. COLORADO: Alamosa Co., Road 150, Zapata Creek, 37°41' N 105°33' W, 2380 m, 4.vi.1994, 2 m; Dolores Co., Road 532 NW slope of Cottonwood Creek, 37°40' N 108°18.5' W, 2380 m, 24.v.2000, 1 m; Rio Blanco Co., Hwy. 139 at Garfield Co. line, 39°39' N 108°48' W, 2176 m, 27.v.1990, 1 m. Holotype and a female paratype will be deposited in the collection of the American Museum of Natural History. Additional paratypes will be deposited in other public museums and in the collections of the authors.

Description of Male (Fig. 1).—Head, vertex dark gray, scales very narrowly white-tipped; frons dark gray with a few scattered whitish scales, mainly dorsolaterally, dorsolateral areas swollen and clearly separated by a trough dorsally and grading into a slight ridge toward the lower margin of the frons; palpi dark gray with whitish scales basally just below eye and at their extreme tips, palpi extending beyond plane of frons by approximately two-thirds of the diameter of the eye, antenna approximately 1 cm in length or 55% of the length of the FW, stalk obscurely speckled gray and whitish; narrow white collar just at base of head and behind a broader collar of white-tipped dark gray scales at the front of the thorax. Thorax above medium gray with white-tipped scales, some scales grayish-brown or dark gray; below white at base of wings shading into pale gray distally; legs clothed with white-tipped medium gray scales. Abdomen gray to grayish brown, sprinkled with a few dark scales especially toward anterior portion of each segment with a terminal row of strongly white-tipped scales along the posterior margin of the first four segments; ventrally paler with heavy sprinkling of white scales; aggregations of dark gray scales along the midline and immediately to each side form three somewhat broken thin dark parallel lines (visible only if there is no abdominal greasing).

Upper Surface of Wings: Forewings, uniform medium gray with only the slightest suggestion of dark scaling forming an indistinct pm line; under magnification a few widely scattered dark scales are visible; fringes concolorous to the naked eye, but under magnification flecked with white and with darker scales at the vein ends. Hind wings concolorous with forewings with a weak accumulation of dark scales at anal angle; fringes as in the forewings.

Under Surface of Wings: Uniformly medium gray with some diffuse speckling by slightly darker scales; hind wing only very slightly lighter in color than forewing.

Length of Forewing: Holotype = 18 mm; range 16–19 mm; average (51 males) 17.75 mm.

Description of Female (Fig. 3).—Similar to the male, except for filiform antennae and shorter and stouter abdomen. Length of Forewing: 16–19 mm; average of 9 females = 17.9 mm.

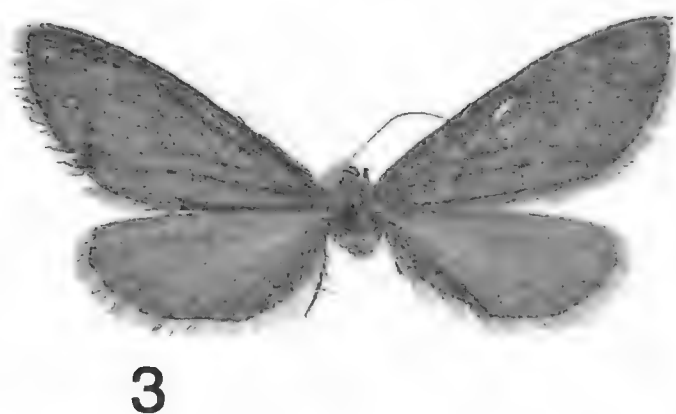
Male Genitalia.—Fifteen specimens dissected. Uncus with width of base just slightly less than length of uncus, lateral margins expanded basally, the apex decurved terminally and ending in a sclerotized point; gnathos with small median enlargement and slightly bilobed apically; valves broadly rounded with slightly angulate outer margin, costa (when not flattened, see left side of Fig. 7) broadly convex and folded, enlarged medially into valve, distally slightly tapered and ending in a setose



HOLOTYPE
Glaucina incognitaria
C. D. Ferris & J. S. Nordin

25 June 2001
black light trap
leg. J.S. Nordin
WYOMING: Albany Co.
T15N R71W Sect. 29
NE of Pole Mt. south of
Happy Jack Rd, El. 8320 ft.

2



PARATYPE No. 01
Glaucina incognitaria
C. D. Ferris & J. S. Nordin

28 June 2001
black light trap
leg. J.S. Nordin
WYOMING: Albany Co.
T15N R71W Sect. 29
NE of Pole Mt. south of
Happy Jack Rd, El. 8320 ft.

4



5

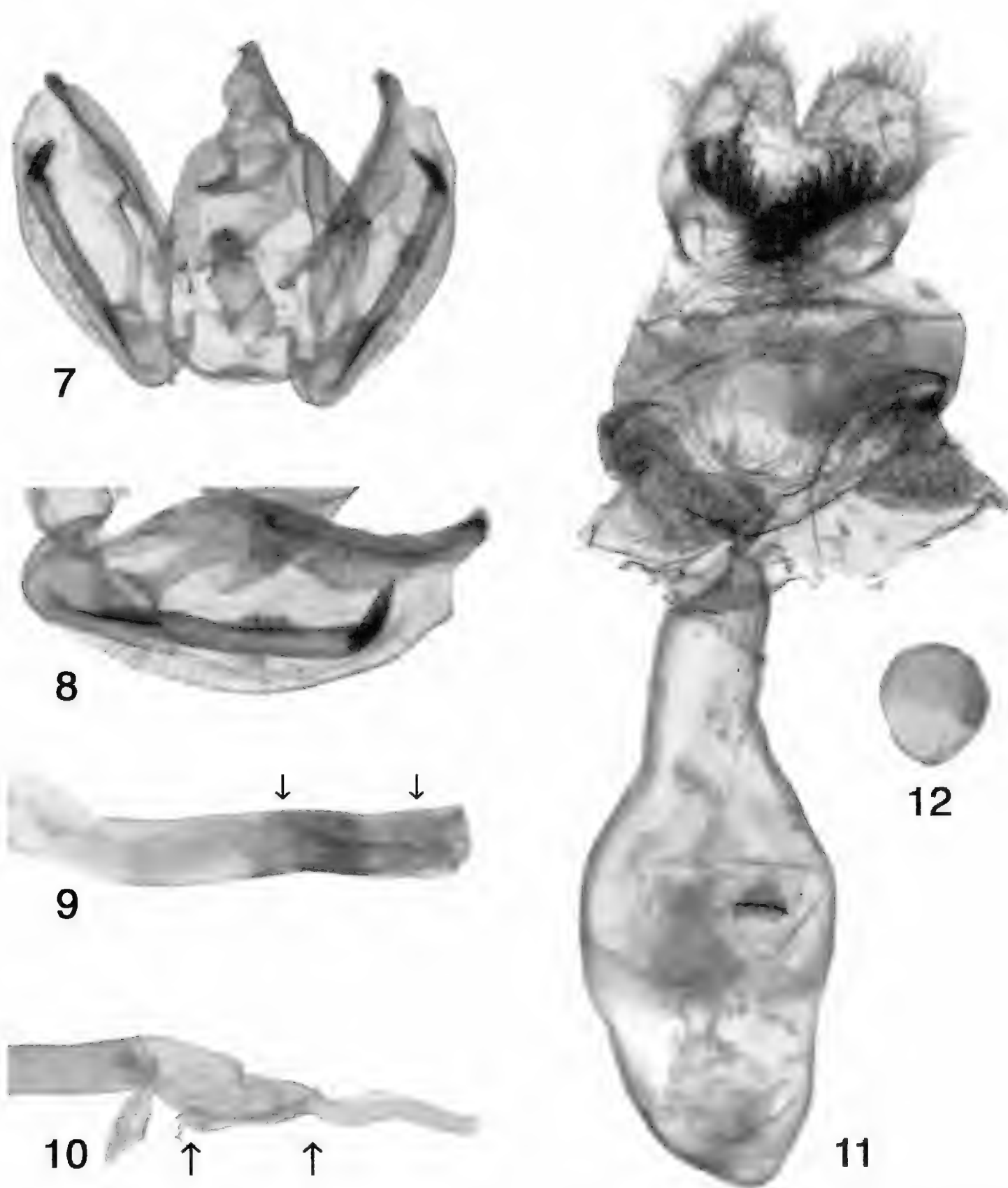


6



Figures 1–6. *Glaucina* species. Figure 1. *Glaucina incognitaria* Ferris & Nordin, holotype male (dorsal). Figure 2. Specimen labels for male holotype; red holotype label. Figure 3. *Glaucina incognitaria* Ferris & Nordin, female paratype (dorsal). Figure 4. Specimen labels for female paratype; yellow paratype label. Figure 5. Male paratype (dorsal) of *G. incognitaria* showing forewing partial median band, Albany Co., WY, 30.vi.2001, J. S. Nordin. Figure 6. *Glaucina nephos* female (dorsal), Albany Co., WY, 21.v.1999, C. D. Ferris.

terminal protuberance; saccus arm long (extending about 0.8 times the length of the costa) and moderately slender with slightly broader width distally, terminating in a rounded apex armed with six spines, two heavy outer spines and four smaller and less robust inner spines (Fig. 8), base of valve with sclerotized band of nonuniform width extending from basal area of inner portion of costal swelling to the sclerotized base of the saccus; median juxta slightly longer than wide with finely pitted surface; saccus wide and broadly convex; aedeagus (Fig. 9) as long as the valves, moderately straight with diameter approximately one-sixth of the length, vesica armed with a slightly curved and slender dentate strip, which upon vesica eversion (Fig. 10) resolves into a membranous narrow band, the surface of the anterior half with triangular projections similar to the teeth of a wood rasp.



Figures 7–12. *G. incognitaria* genitalia. Figure 7. Male, aedeagus removed. Figure 8. Male, right valve (flattened). Figure 9. Male aedeagus, arrows indicate ends of vesica sclerotized band. Figure 10. Male, vesica everted, arrows indicate ends of vesica sclerotized band. Figure 11. Female. Figure 12. Female, detail of lamella postvaginalis.

Female Genitalia (Fig. 11).—Two specimens dissected. Sterigma with a large asymmetrical oval (compressed at top) slightly sclerotized lamella postvaginalis (Fig. 12) bordered anteriorly and laterally by numerous lightly sclerotized folds, with antevaginalis a small medially-indented sclerotized ridge; ductus bursae very short, sclerotized, roughly cylindrical, slightly longer than wide; corpus bursae elongate with tapering sides, with virtually unsclerotized longitudinally striated short tapered neck, neck and body hardly separable, enlarging into terminal, ovoid portion of bursae; prominent signum, transverse with inward-pointing median ridge, located at approximately mid-distance between the base of the ductus bursae and the apex of the corpus bursae; ovipositor lobes typical of the genus.

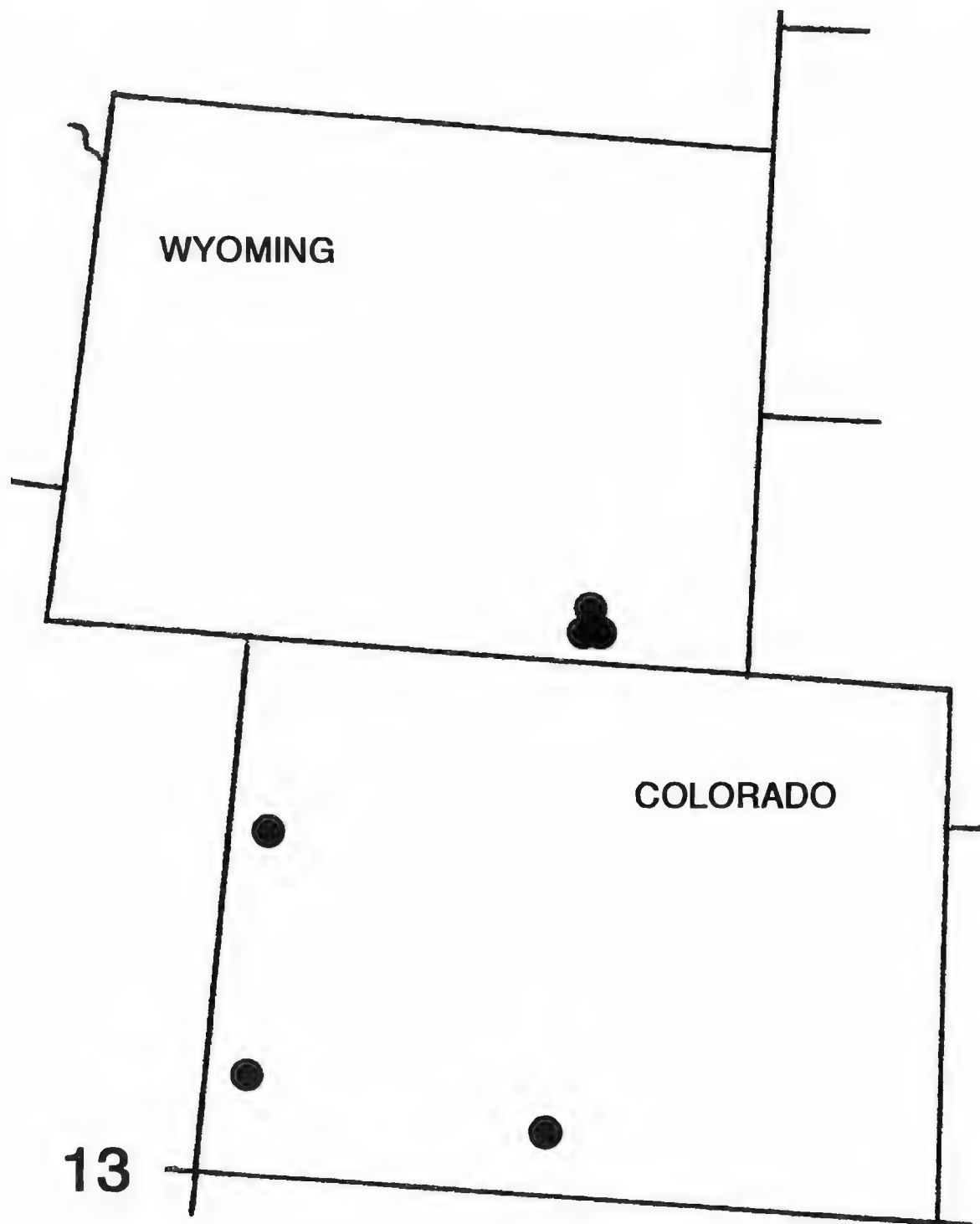


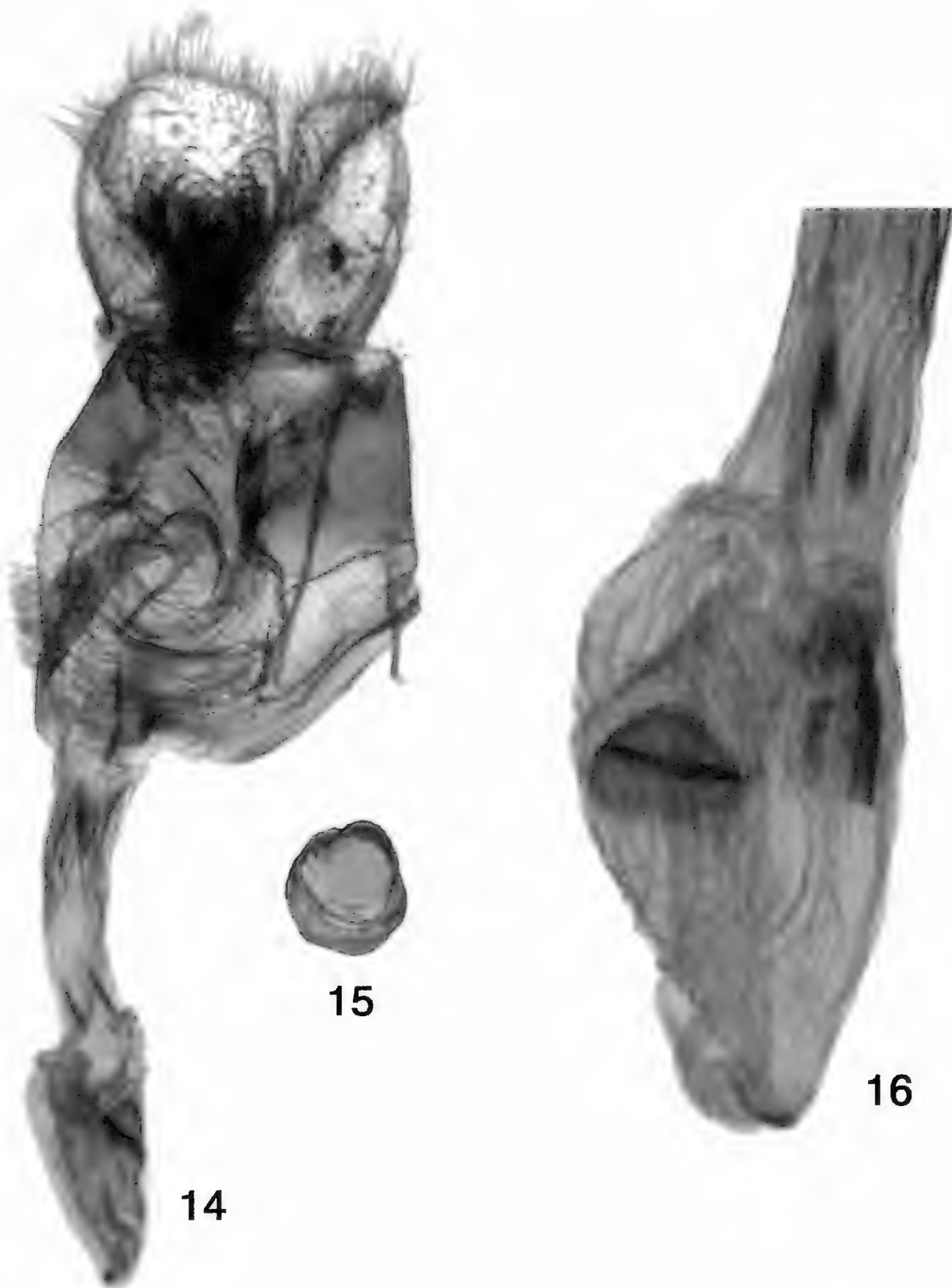
Figure 13. Distribution map for *G. incognitaria*.

Biology and Larval Host.—Unknown. Presence of fine soil particles trapped in the hairs at the tip of the abdomen of female specimens suggests oviposition close to the ground on a low-growing herbaceous plant. With a few exceptions (open prairie), this moth has been taken by black light in moderately dry coniferous environments (spruce-pine in Wyoming).

Distribution.—As is shown in Fig. 15, this moth is known presently from several tightly-grouped localized areas in Albany Co., Wyoming, and from two counties in western and one in extreme south-central Colorado.

Etymology.—The species name reflects the previously unknown status of this moth and is configured to be consistent with the formation of other species names in the genus. A suggested common name is “Unknown Glaucina.”

Diagnosis and Discussion.—On the dorsal forewing in nine males and one female there is the suggestion of antemedial and postmedial lines (Fig. 5), thus forming an open medial band. The only variation in the male genitalia noted was



Figures 14–16. *G. nephos*, female genitalia. Figure 14. Complete, but corpus bursae deflated. Figure 15. Detail of lamella postvaginalis. Figure 16. Corpus bursae showing signum at left side.

in one specimen from Dolores Co., Colorado in which the sacculus apex was armed with seven spines, three large outer spines and 4 smaller inner spines.

Based on the male and female genitalia, *G. incognitaria* is closest to *G. ignavaria* (Pearsall) [Arizona, Colorado, New Mexico] and *G. foeminaria* (Dyar) [Puebla, Mexico], and thus belongs in Group IV of Rindge (1959). In the male genitalia of *G. ignavaria*, the apex of the sacculus is armed with a cluster 5–8 elongate spines with an apical protuberance beyond the spines; in *foeminaria* the

length of the sacculus is considerably shorter than in *G. incognitaria*, and the apex is armed with 2 or 3 robust spines and 2 or 3 short spines.

The overall aspect of the female genitalia in *G. ignavaria* and *G. foeminaria* is similar to that of *G. incognitaria*, with the major differences being the geometry of the ductus bursae and lamella postvaginalis. In *G. ignavaria* the lamella postvaginalis is large and elliptical, while in *G. foeminaria* it is also elliptical, but smaller than in *G. ignavaria*.

In the Rocky Mountain Region the most likely species with which *G. incognitaria* might be confused is *G. interruptaria*. Fresh specimens are easily separated by the lack of distinct dorsal forewing maculation in *G. incognitaria*, in contrast to the well-defined but light maculation in *interruptaria*. Genitalic dissection is required to separate worn specimens. In the male genitalia, the terminal portion of the sacculus arm in *G. interruptaria* is covered by numerous small short spines, while the terminal portion of the sacculus arm in *G. incognitaria* is equipped with two heavy outer spines and four smaller and less robust inner spines. The main characters in the female genitalia that separate the two species are: lamella postvaginalis, essentially trapezoidal with the wider base rounded and convex in *G. interruptaria*, large asymmetrical oval (compressed at top) in *G. incognitaria* with convex top portion much wider than the nearly pointed rounded base; signum, sclerotization nearly symmetrical above and below inward-pointing median ridge in *G. interruptaria*, sclerotization asymmetric about inward-pointing median ridge in *G. incognitaria* with upper portion semicircular and uneven reduced lower portion.

GLAUCINA NEPHOS RINDGE (FEMALE)
(Figs. 5, 14–16)

The female of this species was unknown to Rindge (1959). Males are relatively common in southeast Wyoming at black light, but females do not come readily to light. Over a number of years, the authors have managed between them to obtain 13 female specimens from several localities in Albany Co., Wyoming with collection dates from 18 May to 18 June at elevations from 2270 m to 2500 m. Similarity in wing pattern was used to associate the females with males of *nephos*. Two genitalic dissections were studied.

Description of Female (Fig. 6).—Similar to the male as described by Rindge, except for filiform antennae and shorter and stouter abdomen. The dorsal dark wing markings are less distinct than in the males. Length of Forewing: 16–18 mm; average of 13 females = 17.0 mm.

Female Genitalia (Fig. 14).—Sterigma with a large complex slightly sclerotized lamella postvaginalis (Fig. 15), consisting of a smaller slightly distorted and displaced circle overlying a larger slightly distorted circle, bordered anteriorly and laterally by a few lightly sclerotized folds, with antevaginalis a small shallowly medially-indented sclerotized ridge; ductus bursae challis-like, sclerotized, flared laterally at top and tapering to the junction with the neck of the corpus bursae, slightly shorter than wide; corpus bursae (Fig. 16) with well-defined neck, in length at least half of length of corpus bursae, very weakly striated and dotted with small pits just below junction with ductus bursae, enlarging into an apically tapering terminal bulb; prominent signum, transverse with narrow inward-pointing median ridge, located at approximately mid-length of the tapered bulb; ovipositor lobes typical of the genus.

Biology.—The biology and host plant of this species remain unknown.

Observation.—Both *G. incognitaria* and *G. nephos* occupy the same habitats and may be taken at light on the same night, however the known geographic

range of *G. nephos* is much greater [Arizona, Colorado, Idaho, Wyoming] than that currently known for *G. incognitaria*. *G. nephos* is also a Group IV species.

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Rindge, F. H. 1959. A Revision of *Glaucina*, *Synglochis*, and *Eubarnesia* (Lepidoptera, Geometridae). Bulletin AMNH, 118 (6): 259–366.

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CHINESE SPECIES OF THE JUMPING SPIDER GENUS *PORTIA* KARSCH (ARANEAE: SALTICIDAE)

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Abstract.—The present paper presents a revision of Chinese *Portia* spiders. A total of six species, including one new species—*Portia wui* Peng & Li, are known from China. Descriptions of new species and diagnosis of known species are given. Distributional data, a key to Chinese species, and illustrations of body and genital organs are provided.

Key Words.—Araneae, Salticidae, *Portia*, revision, new species, China.

The spider genus *Portia* was erected by Karsch (1878: 774) to accommodate *Portia schultzei* Karsch. Most known species of *Portia* distributed in the Oriental region, few in the Ethiopia. To have a better understanding on Chinese representatives of this jumping spider genus, we have examined the specimens of *Portia* deposited in the Institute of Zoology, Chinese Academy of Sciences (IZCAS), Hunan Normal University (HNU), and Lanzhou University (LZU). Results of this museum survey are reported in the present paper.

Descriptions were made based on specimens fixed in 80% ethanol. Specimens were examined and figured under SZ40-Olympus stereomicroscope. Epigynum was figured before it was dissected from the spider abdomen, while vulva was figured after it was macerated in lactic acid. The sequence of leg segments in measurement data is as follows: Total (femur, patella + tibia, metatarsus, tarsus). Measurements are given in millimeter (mm). Terminology adopted is that used by Wanless (1978).

Abbreviations used: AER-anterior eye row, AL-abdominal length, ALE-anterior lateral eye, AME-anterior median eye, AW-abdominal width, BTA-basal tibial apophyses, CD-conductor, CL-carapace length, CLYH-clypeus height, CW-carapace width, E-embolus, EFL-length of eye field, ITA-intermediate tibial apophyses, PER-posterior eye row, PLE-posterior lateral eye, RTA-retrolateral tibial apophyses, SD-sperm duct, T-tegulum, TA-tegular apophysis, TF-tegular furrow, TL-total length, VTA-ventral tibial apophysis.

PORTIA KARSCH, 1878

Sinis Thorell, 1878, Ann. Mus. civ. stor. nat. Genova 13: 269. Type species *Salticus fimbriatus* Doleschall, 1859 by original designation.

Portia Karsch, 1878, Zeitschr. ges. Naturw 51: 744. Type species *Portia schultzei* Karsch, 1878 by original designation.

Boethoportia Hogg, 1915, Proc. Zool. Soc. Lond. 1915: 501. Type species *Boethoportia ocellata* Hogg, 1915.

Neccocalus Roewer, 1965, Annls Mus. r. Afr. cent. (*Sci. Zool.*) 139: 20. Type species *Cocalus africanus* Thorell, 1899 by original designation.

Type Species.—*Portia schultzei* Karsch, 1878, by original designation.

Diagnosis.—Medium to large spiders ranging from about 4.50 to 9.50 in length. Carapace high and elevated; usually with marked slope from PLE to posterior

margin of carapace; PME well developed, almost as big as ALE, about midway between ALE and PLE or closer to ALE; PER usually narrower than AER; EFL about 35–55 percent of carapace. Chelicera with 3 promarginal teeth and 3–6 retromarginal. Legs slender and long, with conspicuous fringes, spines numerous and strong. Abdomen usually ornate with tufts of hairs. Male palpal organ: bulb oval; embolus usually long and slender; tegulum with a deeply curved furrow, and sometimes with a small apophysis; tibia with numerous apophyses; cymbium usually with distinct flange. Epigynum weakly sclerotized, openings small and usually unclear; compulactory ducts short, wide and strongly sclerotized; spermathecae oval and big.

Portia is represented by 14 species worldwide, including 1 new species described in this paper. These include—*Portia albigimana* (Simon, 1900) (India to Vietnam), *P. assamensis* Wanless, 1978 (India to Malaysia), *P. crassipalpis* (Peckham & Peckham, 1907) (Singapore, Borneo), *P. fimbriata* (Doleschall, 1859) (Nepal, Sri Lanka to Australia), *P. heteroidea* Xie & Yin, 1991 (China), *P. hoggi* Zabka, 1985 (Vietnam), *P. jianfeng* Song & Zhu, 1998 (China), *P. labiata* (Thorell, 1887) (Sri Lanka to Philippines), *P. orientalis* Murphy & Murphy, 1983 (China), *P. quei* Zabka, 1985 (China, Vietnam), *P. schultzi* Karsch, 1878 (Central, East, Southern Africa, Madagascar), *P. songi* Tang & Yang, 1997 (China), *P. strandi* Caporiacco, 1941 (Ethiopia) and *P. wui* n. sp. (China). Up to now, a total of 6 *Portia* species including *P. orientalis* Murphy and Murphy, 1983 have been recorded from China.

KEY TO CHINESE SPECIES OF *PORTIA*

- 1. Male 2
- Female 7
- 2. Tibia with more than 3 apophyses (Figs. 1C, 2B) 3
- Tibia with 3 apophyses 4
- 3. Embolus slender and long, encircled with conductor basely in ventral view
..... *P. jianfeng* (Fig. 1B)
- Embolus short with much larger base and sharp end, conductor invisible
..... *P. songi* (Fig. 2B)
- 4. Cymbium with a horn-shaped apophysis in addition to flange (Figs. 3C, 3D) *P. wui*, NEW SPECIES
- Cymbium without apophysis, only with flange 5
- 5. Tegulum furrow with deep curve *P. quei*
- Tegulum furrow with shallower curve 6
- 6. Chelicera with 4 retromarginal teeth, retrolateral tibial apophysis bar-like, with smooth end *P. heteroidea*
- Chelicera with 3 retromarginal teeth, retrolateral tibial apophysis longer with sharp end *P. orientalis*
- 7. Spermathecae spherical 8
- Spermathecae (Fig. 2G) about cylindrical, its length twice its width
..... *P. songi*
- 8. Epigynum with developed median septum, atrium circular ... *P. heteroidea*
- Epigynum without septum, atrium transverse, slit-like *P. quei*

PORTIA HETEROIDEA XIE & YIN, 1991

Portia heteroidea Xie & Yin, 1991: 31, figs. 5–13 (male & female); Peng et al., 1993: 187, figs. 653–659 (male & female); Song, Chen & Zhu, 1997: 1740, figs. 53a–c (male); Song, Zhu & Chen, 1999: 541, figs. 311J, 312E (male & female).

Diagnosis.—Embolus of median length, its terminal end extended slightly beyond the retrolateral margin of cymbium in ventral view. Three tibial apophyses, ventral apophyses short, conic; intermediate apophyses smallest and shortest; retrolateral apophyses biggest and longest, bar-like, slightly swollen terminally. Tegulum furrow procurved arc-like, shallow; no tegular apophysis. In dorsal view, cymbium flange long and robust, its upper base originated from the median portion of cymbium, its end extended to median front margin of tibial apophysis. Epigynum with large atria, almost circular; median septum developed, posterior margin wider with slight incision; spermathecae big spherical, compulsory duct invisible. Abdomen with 5 yellow-brown circles, posterior 3 circles covered by gray-white hairs. This species is closely related to *P. quei* Zabka, 1985, but differs in: 1) embolus shorter; 2) retrolateral tibial apophysis shorter with round end, that of *P. quei* with hook-like end; 3) atria larger and almost circular, that of the latter wide slit-like; 4) epigynum with median septum which is absent in that of the latter.

Specimens Examined.—1 female, deposited in IZCAS, data: CHINA, SHAANXI PROVINCE, FUPING COUNTY Co.: 33.5° N, 108.0° E, 870–1000 m, 25 Jul 1998, by Chen Jun; 1 male, deposited in IZCAS, data: CHINA, GANSU PROVINCE, WENXIAN COUNTY Co.: 32.9° N, 104.7° E, 900–1500 m, 25 Jun 1998, by Chen Jun.

Distribution.—China (Gansu, Shaanxi, Hunnan, Hubei, Guizhou, Sichuan).

PORTIA JIANFENG SONG & ZHU, 1998

(Fig. 1)

Portia jianfeng Song & Zhu, 1998: 26, figs. 1–3 (male); Song, Zhu & Chen, 1999: 541, figs. 311 K–L (male).

Diagnosis.—Embolus belt-like, tapering distally; conductor well developed, enclosing the base of embolus in ventral view; tegulum long and diagonal, lower end almost extended to the right bottom of the bulb; tegulum apophysis developed, thin and triangular. 4 tibial apophyses: 3 in upper row, ventral one most stout; intermediate one short horn-like, bent ventrally in retrolateral view; retrolateral apophysis finger-like in retrolateral and dorsal views; basal apophysis biggest and very swollen, almost spherical in retrolateral view, and diagonal oblong in dorsal view. Abdomen with 2 gray longitudinal bands and pairs of gray patches. This species is allied to *P. songi* Tang & Yang, 1997, but can be distinguished from the latter by: 1) embolus much longer and thinner (Figs. 1B, 1C, 2B, 2C); 2) conductor well developed (Figs. 1B, 1C), enclosing the base of embolus in ventral view (Fig. 1B), that of *P. songi* without conductor (Figs. 2B, 2C, 3); 3) tegulum furrow almost longitudinal (Fig. 1B) in ventral view, that of *P. songi* almost transverse (Fig. 2B); 4) cymbium thinner and longer (Figs. 1B–1D, 2B–2D); 5) abdominal patterns also quite different (Figs. 1A, 2A).

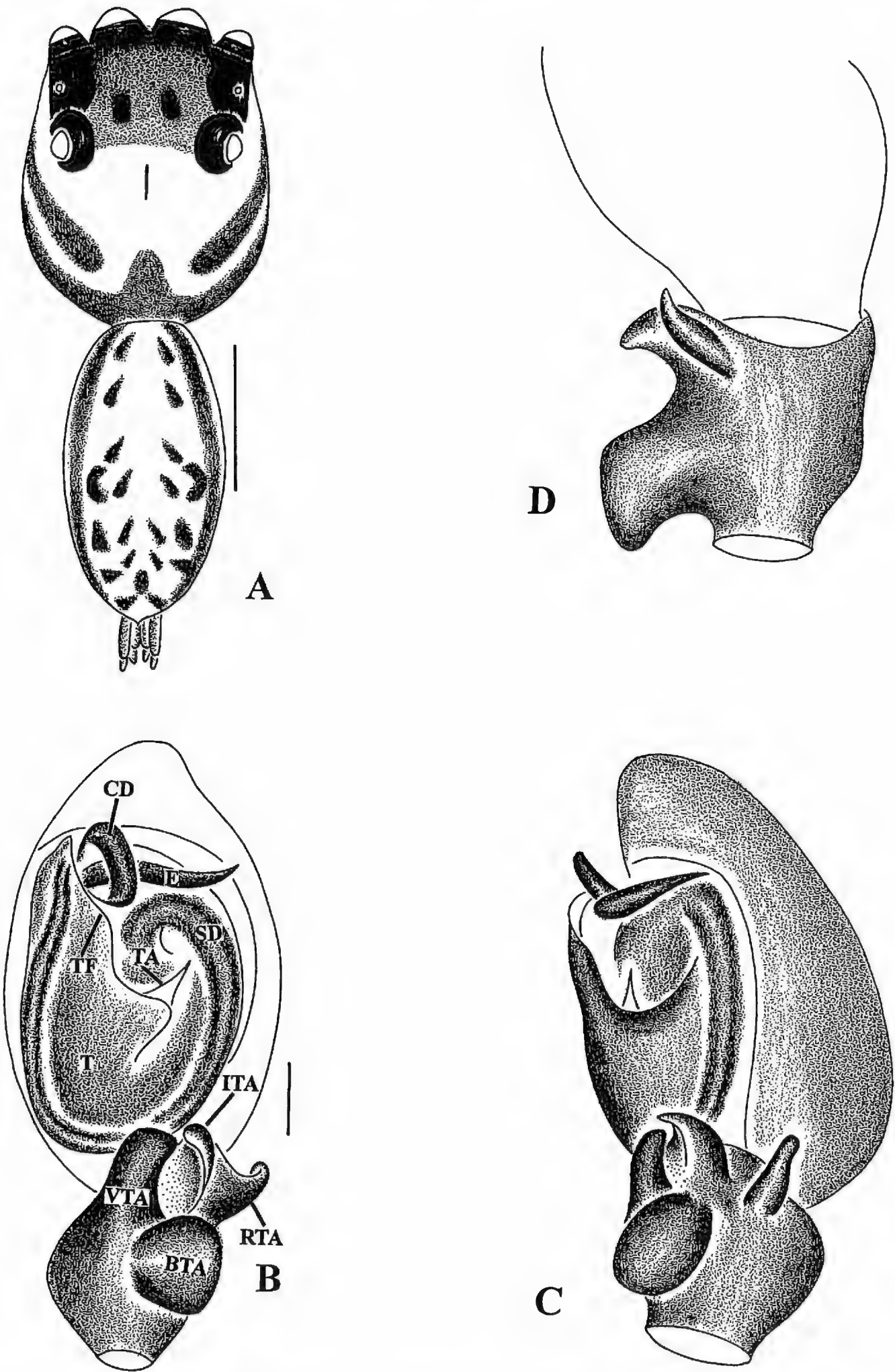


Figure 1. *Portia jianfeng* Song & Zhu, 1998. Figure 1A. Body of male, dorsal view. Figure 1B. Left palpal organ, ventral view. Figure 1C. Left palpal organ, retrolateral view. Figure 1D. Tibial apophysis, dorsal view. Scale bar: Figure 1A = 1.00 mm, Figure 1B–Figure 1D = 0.10 mm.

Specimens Examined.—2 males, deposited in IZCAS, data: CHINA, HAINAN PROVINCE, LE-DONG COUNTY, JIANFENGLING Co.: 18.7°N, 109.1°E, Apr 1994, by Liao Cong-Hui.

Distribution.—China (Hainan).

PORTIA ORIENTALIS MURPHY & MURPHY, 1983

Portia orientalis Murphy & Murphy, 1983: 40, figs. 6, 9, 12, 16, 20 (male).

Diagnosis.—Embolus long and thin, narrowing gradually, terminal end extended beyond the retrolateral margin of cymbium in ventral view. Tegulum furrow curve shallow and narrow, tegular apophysis indistinct. 3 tibial apophyses, ventral apophysis very short, hook-like in retrolateral view; intermediate apophysis thin, very pale, covered by a tuft of long white hairs; retrolateral apophysis longest, terminal end hook-like in retrolateral view. In dorsal view, cymbium flange long and large, overlapping dorsum of retrolateral tibial apophysis, terminal end beyond the retromargin of tibial apophysis. This species resembles *P. assamensis* Wanless, 1978, but can be separated from the latter by: 1) retrolateral tibial apophysis longer and thinner; 2) cymbial flange stouter and shorter; 3) embolus longer.

Specimens Examined.—Type specimen was collected from Hong Kong and deposited in British Museum. No further specimens were collected from China. No specimens were examined in this study. The above information is after Murphy and Murphy (1983).

Distribution.—China (Hong Kong).

PORTIA QUEI ZABKA, 1985

Portia quei Zabka, 1985: 438, figs. 497–501 (male); Song, Chen & Gong, 1990: 15, figs. 1–4 (male & female); Chen & Zhang, 1991: 314, figs. 334.1–6 (male & female); Peng et al., 1993: 188, figs. 660–666 (male & female); Song, Zhu & Chen, 1999: 541, figs. 311M–N, 312F–G (male & female).

Diagnosis.—Embolus very long and thin, narrowing gradually, more than one third extended beyond the retrolateral margin of cymbium in ventral view; tegular furrow curve very deep, tegular apophysis indistinct. Three tibial apophyses, ventral apophysis thin and short, hook-like, bent retrolaterally; intermediate apophysis also very short, conical in retrolateral view; retrolateral apophysis long and thin, terminal portion hook-like. Cymbium flange thin, terminal portion overlapping on median portion of retrolateral tibial apophysis. Epigynum with wide slit-like atrium near epigastric groove, no median septum. Spermathecae big and spherical, compulsory duct invisible. This species is closely allied to *Portia heteroidea*. Differences between them are discussed in the diagnosis of *Portia heteroidea*.

Specimens Examined.—4 males, 6 immatures, deposited in HNU, data: CHINA, YUNNAN PROVINCE, NUJIANG COUNTY, QIQI Co.: 27.7° N, 98.7° E, 9–14 Jul 2000; 4 females, 3 immatures, deposited in HNU, data: CHINA, YUNNAN PROVINCE, GONGSHAN COUNTY Co.: 27.7° N, 98.6° E, 29 Jun 2000; 1 male, deposited in IZCAS, data: CHINA, GUANGXI ZHUANG AUTONOMOUS REGION, JINXIOU COUNTY CO.: 24.1° N, 110.1° E, 490 m, 1 Jul 2000, by Chen Jun; 1 female, deposited in IZCAS, data: CHINA, GUANGXI ZHUANG AUTONOMOUS REGION, JINXIOU COUNTY CO.: 24.1° N, 110.1° E, 1050–1100 m, 2 Jul 2000, by Chen Jun.

Distribution.—China (Hunan, Hubei, Guangxi, Sichuan, Guizhou, Yunnan), Viet Nam.

PORTIA SONGI TANG & YANG, 1997

(Fig. 2)

Portia songi Tang & Yang, 1997: 353, figs. 1–8 (male & female); Song, Zhu & Chen, 1999: 541, figs. 311O–P, 312H, 313A, 328Q (male & female).

Diagnosis.—Embolus short, basal portion large, terminal portion spine-like; tegular furrow slightly diagonal, tegular apophysis short and large; median apophysis short, conic. 5 tibial apophyses: ventral apophysis biggest, conic; retrolateral apophysis longest, terminal portion hook-like in ventral and dorsal views; in ventral view, 3 intermediate apophyses arranged in a line, top one longest and finger-like, median one shortest and conic, bottom one biggest and conic. Cymbium flange big and short in retrolateral view. Epigynum longer than wide, transparent, 2 belts looped near epigastric furrow; spermathecae with 2 chambers, length twice its width; compulsory duct invisible. This species is allied to *P. jianfeng* Song & Zhu, 1998. Differences between them are discussed in the diagnosis of *P. jianfeng*.

Specimens Examined.—1 male, 1 female, deposited in LZU, data: CHINA, GUNSU PROVINCE, WENXIAN COUNTY Co.: 32.9° N, 104.7° E, Jun 1992, by Tang Ying-Qiu.

Distribution.—China (Gansu).

PORTIA WUI PENG & LI, NEW SPECIES

(Fig. 3)

Type.—Holotype, male, deposited in IZCAS, data: CHINA, GUANGXI ZHUANG AUTONOMOUS REGION, NAPO COUNTY, PINGMENG TOWN, BEIDOU TOWNSHIP, Co.: 23.4° N, 105.8° E, 500–550m, 10 Apr 1998, By WU Min (No. WM98GXsp.25).

Measurements.—Male: TL 6.60, CL 3.00, CW 2.70, AL 3.60, AW 1.60; legs: I 12.50 (3.10, 4.50, 3.40, 1.50), II 10.00 (2.50, 4.00, 2.50, 1.00), III 9.40 (2.50, 3.60, 2.30, 1.00), IV 12.80 (3.20, 4.00, 4.40, 1.20), formula 4, 1, 2, 3. AER 2.10, PER 1.90, AME 0.75, ALE 0.35, PME 0.25, PLE 0.30, EFL 1.40, CLYH 0.50.

Description.—Male (holotype): Carapace (Fig. 3A) brown; ocular area light brown, base of AME brown, the other eyes surrounded with black bases; fovea black, longitudinal line-shaped; cervical and radial grooves black. Sternum yellow-brown, densely clothed in white and brown hair; margin dark brown with irregular black patches. Clypeus dark gray-brown, clothed in sparse hair; front margin gray-black. Chelicera dark gray-brown, anterior side darker, distal area and furrow margin clothed in gray-brown brush-like hair; furrow with 2 promarginal teeth and 3 retromarginal denticles (Fig. 3E). Endites and labium gray-black, distal area and inner sides clothed in gray-black long hair. Legs gray-brown with lighter annuli; ventral sides of tibiae and patellae clothed in dense brush-like long hair, which on tibia II is much denser and covers three fourth portion of tibia II; hair on the rest of segments very sparse; spines sparse and weak, 3 pairs on ventral sides of tibiae I and II, 2 pairs on ventral sides of metatarsi I and II. Abdomen cylindrical. Dorsum (Fig. 3A) gray-white with gray-black marks; cardiac pattern long bar-shaped, 2 muscular depressions darker and clear. Ventral side gray-black; each anterior side with a gray-white patch; 2 small gray-white circles on posterior median area. Spinnerets black brown. Palpal organ (Figs. 3B–D): embolus short and stout; seminal duct clear and S-shaped; 3 tibial apophyses, ventral one large and short, intermediate one smallest and finger-shaped, retrolateral one biggest and flag-shaped in dorsal view; cymbium flange slender and short; cymbium apophysis stout and horn-shaped.

Female.—Unknown.

Diagnosis.—The new species resembles *Portia heteroidea* Xie & Yin, 1991, but differs in: 1) embolus shorter and stouter; 2) retrolateral tibial apophysis much

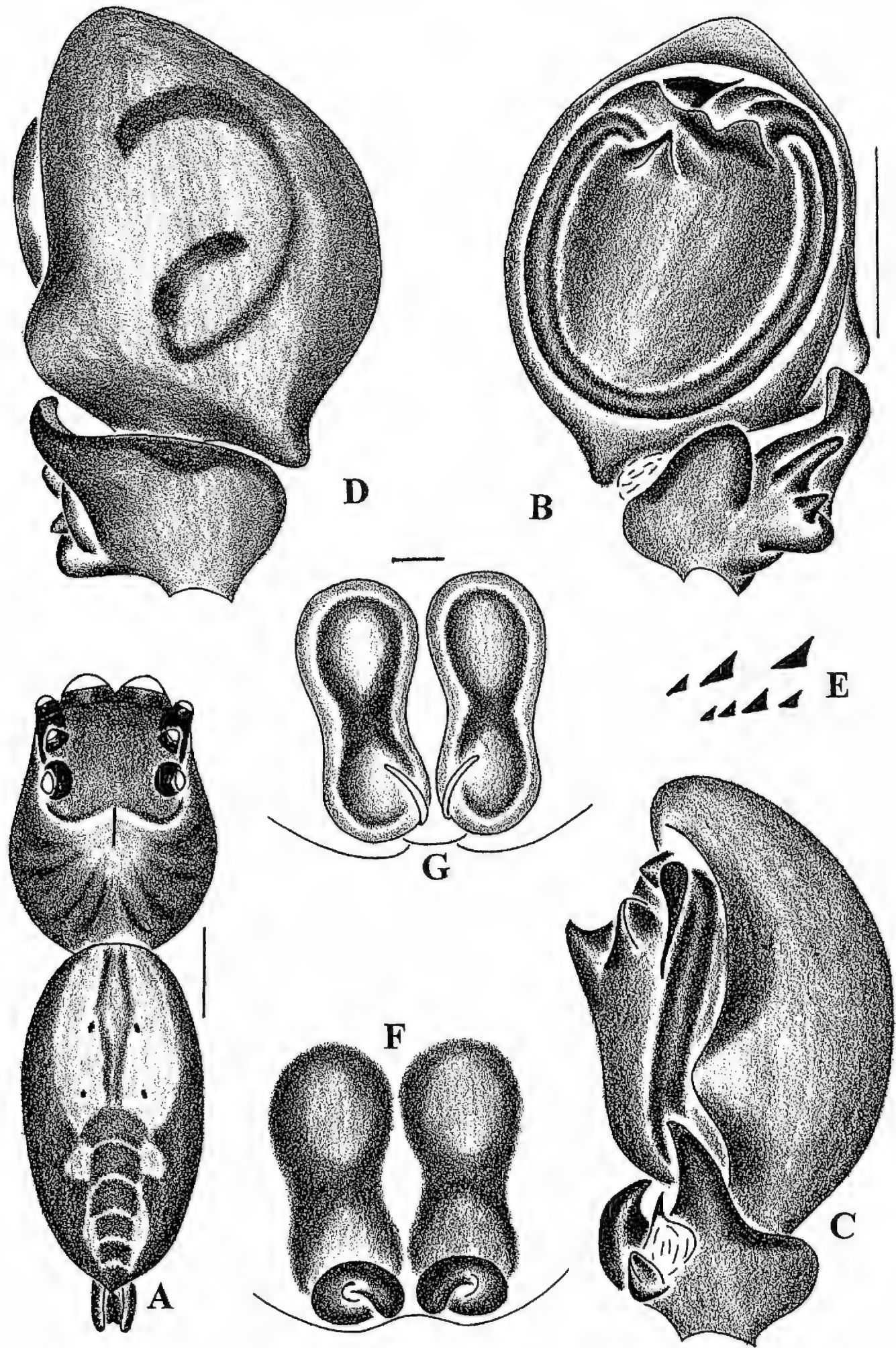


Figure 2. *Portia songi* Tang & Yang, 1997. Figure 2A. Body of male, dorsal view. Figure 2B. Left palpal organ, ventral view. Figure 2C. Left palpal organ, retrolateral view. Figure 2D. Left palpal organ, dorsal view. Figure 2E. Teeth of left male chelicera: upper—promargin, lower—retromargin. Figure 2F. Epigynum. Figure 2G. Vulva, dorsal view. Scale bar: Fig. 2A = 0.10 mm, Fig. 2B–Fig. 2D = 0.50 mm, Fig. 2F–Fig. 2G = 0.10 mm.

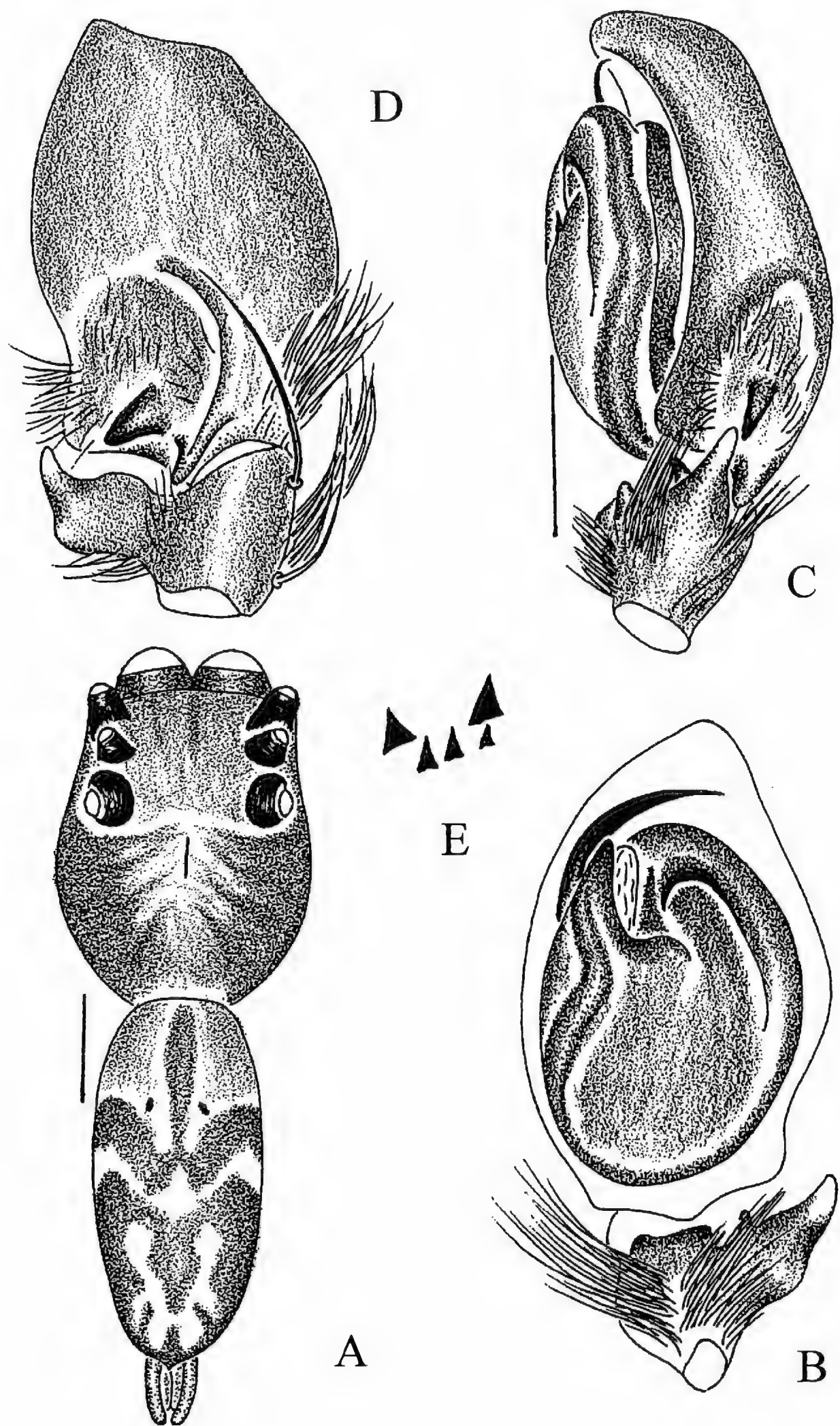


Figure 3. *Portia wui* Peng & Li, sp. nov. Figure 3A. Body of male. Figure 3B. Left palpal organ, ventral view. Figure 3C. Left palpal organ, retrolateral view. Figure 3D. Left palpal organ, dorsal view. Figure 3E. Teeth on left chelicera: upper—promargin, lower—retromargin. Scale bar: Fig. 3A = 1.00 mm, Fig. 3B–Fig. 3D = 0.5 mm.

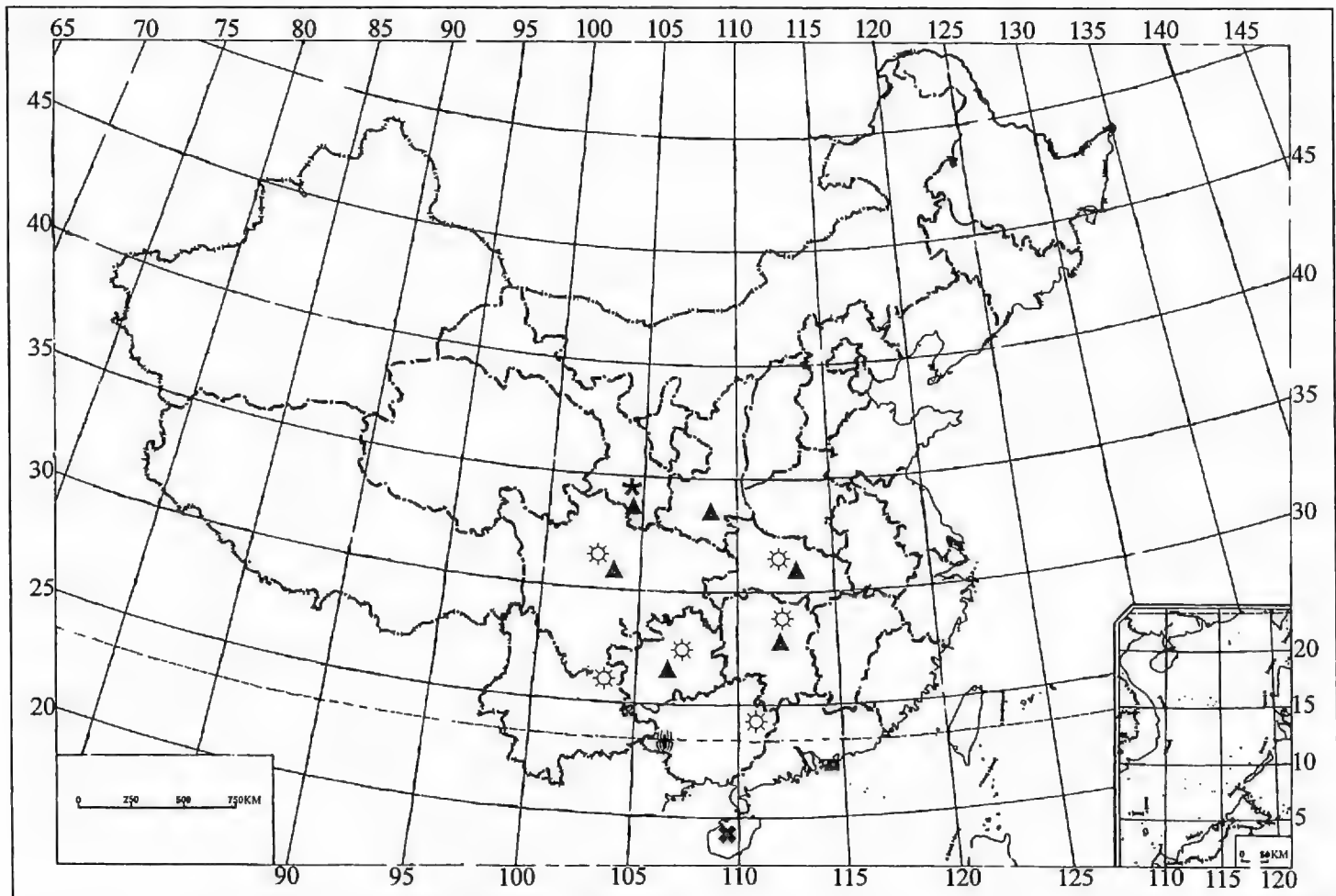


Figure 4. Distribution of Chinese Species of *Portia*. ▲ *Portia heteroidea*, ✕ *Portia jianfeng*, ■ *Portia orientalis*, ☆ *Portia quei*, ★ *Portia songi*, ■ *Portia wui*.

bigger, flag-shaped in dorsal view (Fig. 3D), that of the latter bar-shaped; 3) cymbium flange (Fig. 3D) much shorter and more slender; 4) cymbium with a stout horn-shaped apophysis (Figs. 3C, 3D) nearing cymbium flange, which cannot be found in any other known species of the genus; 5) abdominal marks much more distinct.

Etymology.—The new species is named in honor of Dr. WU Min, who collected the type specimen.

Distribution.—China (Guangxi).

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We are very grateful to Prof. YIN Changmin (HNU) for her continued support and encouragement during our study on Chinese jumping spiders. Our special thanks should be given to Dr. Wu Min (IZCAS) for his donation of the type of *Portia wui* Peng & Li, sp. nov., and to Prof. Tang Yingqiu (LZU) for supplying materials used in this study.

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NEW GENERA AND NEW SPECIES OF NEOTROPICAL NEMATOPODINI (HEMIPTERA: HETEROPTERA: COREIDAE: COREINAE)

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Abstract.—Two new genera (*Nectoquintius* and *Stenoquintius*) and three new species (*Nectoquintius alajuelensis*, *Stenoquintius matogrossensis*, and *Stenoquintius reclusa*) from Brasil, Costa Rica, Ecuador and Venezuela are described in the tribe Nematopodini (Coreidae), and compared with the related genera *Grammopoecilus* Stål, *Nematopus* Berthold, *Quintius* Stål, and *Saguntus* Stål. Dorsal habitus illustrations and drawings of antennae, hind legs, and male genital capsule are provided.

Key Words.—Insecta, Hemiptera, Heteroptera, Coreidae, Nematopodini, new genera, new species, neotropical region.

The Nematopodini Amyot and Serville a New World tribe of the coreid subfamily Coreinae, is large and diverse. Members of this tribe are extremely abundant in the neotropics and despite the diversity of the fauna, many taxa remain undescribed. The twenty genera and one subgenus recognized in this tribe, have been revised recently by O'Shea (1980) and Brailovsky (1986, 1987, 1995).

The Nematopodini are characterized by the hind femur ventrally armed, and usually strongly incrassate especially in males, tibiae sulcate, hind tibiae unarmed at apex; tylus projecting slightly beyond juga, antenniferous tubercles unarmed, occupying most of anterior head, ocellar tubercles small; metathoracic peritreme with two completely separated lobes and area between them depressed, and abdominal sterna unarmed in both sexes (O'Shea 1980, Packauskas 1994).

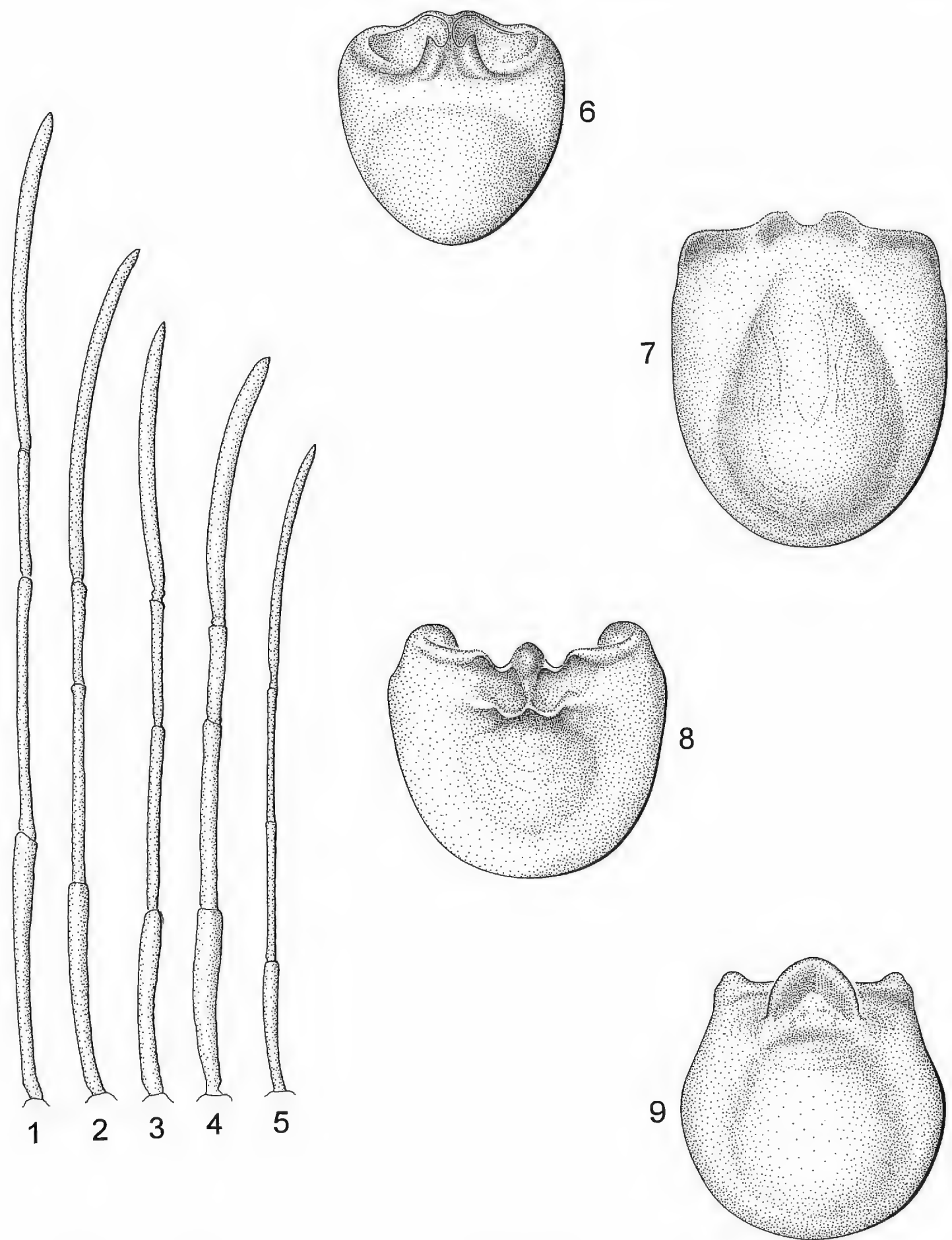
In the present paper we describe two new genera and three new species from Brasil, Costa Rica, Ecuador and Venezuela.

All measurements are in millimeters.

NECTOQUINTIUS BRAILOVSKY AND BARRERA, NEW GENUS

TYPE SPECIES.—*NECTOQUINTIUS ALAJUELENSIS* BRAILOVSKY AND BARRERA,
NEW SPECIES.

Description.—Body medium sized, relatively narrow and elongate. Head: Wider than long (across eyes), pentagonal, and declivant anteriorly; tylus unarmed, apically globose, raised, extending anteriorly to and laterally higher than juga; juga unarmed, laterally expanded and thickened; antenniferous tubercle broad, widely separated, diverging anteriorly and unarmed; antennal segment I thicker than succeeding segments, and slightly curved outward; segments II and III, cylindrical and slender; segment IV fusiform; antennal segment IV the longest, III the shortest, and I longer than II (Fig. 1); preocellar pit deep; ocellar tubercle small; eyes hemispherical, prominent; postocular tubercle moderately protuberant; buccula rounded, short, raised, not projecting beyond antenniferous tubercle, without teeth, and closed posteriorly; tip of rostrum reaching middle third of mesosternum; genae and mandibular plate unarmed. Thorax. Pronotum: Wider than long, trapeziform, shallowly declivant; collar wide; frontal angles rounded; anterolateral borders obliquely straight, entire; humeral angles obtusely rounded; posterolateral borders sinuate; posterior border straight; triangular process narrow, apically subacute; calli transverse and conspicuously raised, and uniformly tuberculate. Anterior lobe



Figures 1–5. Antennae. Figure 1. *Nectoquintius alajuelensis*, new genus, new species. Figure 2. *Quintius scenicum* Brailovsky and Barrera. Figure 3. *Stenoquintius reclusa* new genus, new species. Figure 4. *Quintius dentifer* Stål. Figure 5. *Saguntus pallens* (Walker). Figures 6–9. Male genital capsule. Figure 6. *Saguntus pallens* (Walker). Figure 7. *Stenoquintius reclusa* new genus, new species. Figure 8. *Nectoquintius alajuelensis* new genus, new species. Figure 9. *Quintius dentifer* Stål.

of metathoracic peritreme reniform, weakly elevated, posterior lobe sharp, small; mesosternum lacking longitudinal furrow. Legs: Femora not strongly incrassate, and ventrally armed with one subapical small teeth; tibiae unarmed, cylindrical, and sulcate; hind tibiae longer than hind femur; basal segment of hind tarsi longer than total length of middle and hind segment together (Fig. 10). Scutellum: Triangular, flat, longer than wide, with apex subacute. Hemelytra: Macropterous, reaching or extending beyond the apex of last abdominal segment; costal margin emarginate; apical margin almost obliquely straight. Abdomen: Lateral margins parallel; posterior angle of connexivum extending into short and acute spine; abdominal spiracle clearly elliptic, closed to anterior margin; abdominal sterna lacking medial furrow. Integument: Body surface shining; pronotum, scutellum, clavus, corium, propleura, posterior third of mesopleura and metapleura, acetabulae, and male genital capsule punctate; head, apex of scutellum, connexivum, prosternum, mesosternum and metasternum, anterior third of mesopleura and metapleura, abdominal sterna, and female genital plates impunctate; scutellum transversely striate; dorsal surface glabrous; ventrally with few long bristle-like setae located into the sternal surface of thorax, and on the abdominal sterna; pubescence of antennal segments and tibiae short, mainly appressed, on rostral segments II to IV, femora, and tarsi longer, suberect to erect and rather dense; calli densely tuberculate.

Male Genitalia.—Genital capsule broadly ovoid; posteroventral edge with broad tooth-like projection at middle third, laterally deeply concave, and with lateral angles exposed, and subtruncated (Fig. 8).

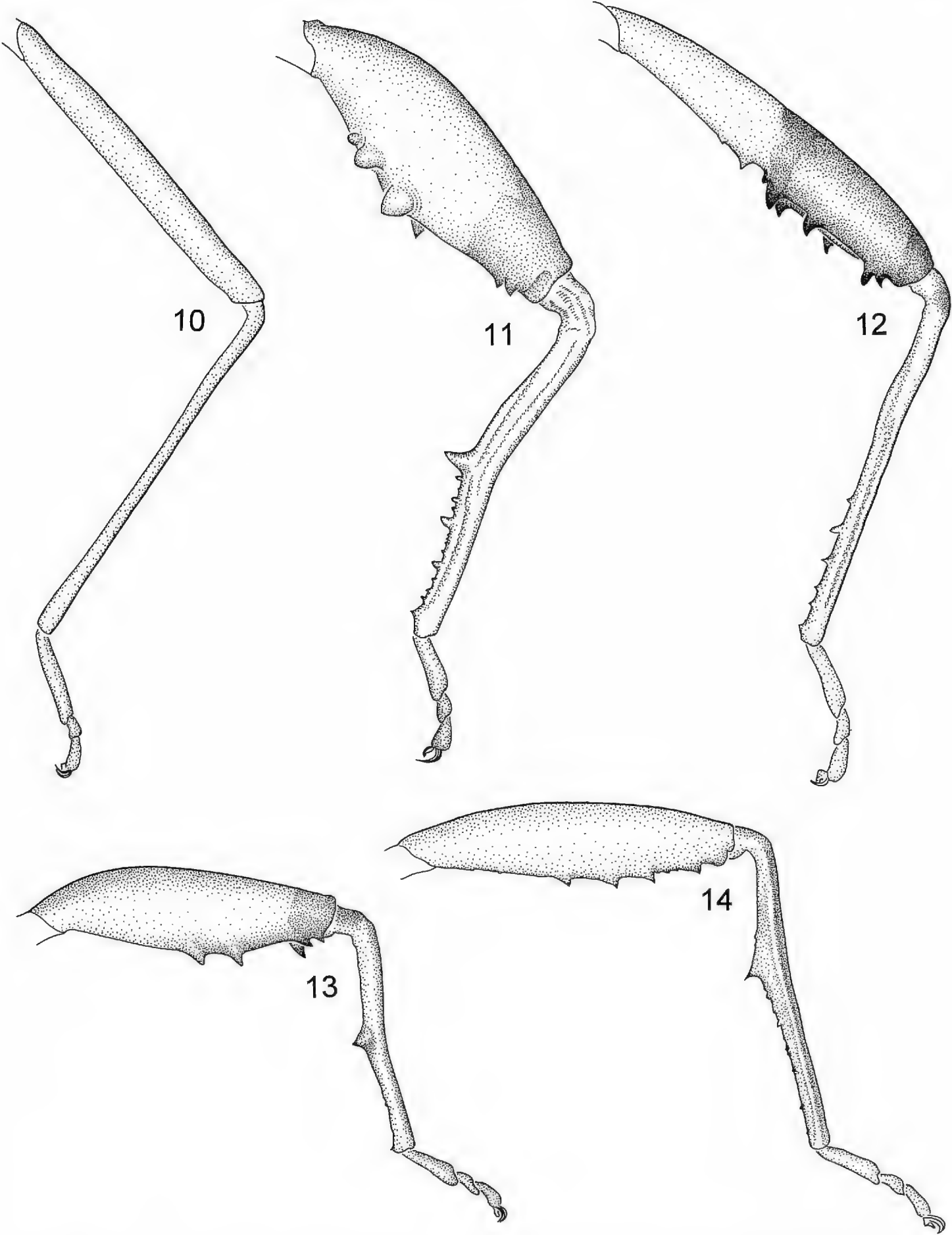
Female Genitalia.—Abdominal sternite VII with plica and fissura; the former curved, reduced, and transversely straight, the fissura with inner margin overlapping; gonocoxae I triangular, closed in caudal view, and with upper border rounded; paratergite VIII subtriangular with spiracle visible; paratergite IX squarish, and larger than paratergite VIII.

Discussion.—This genus runs to O'Shea (1980) key at couplet 7 and its related particularly with *Quintius* Stål and *Saguntus* Stål.

The relatively narrow and elongate body, the rounded humeral angles, the clearly elliptical abdominal spiracles close to the anterior margin, the ventrally armed femora, the cylindrical tibiae that are never dilated, the longer than wide scutellum, and the mesosternum lacking a longitudinal furrow suggest a relationship with *Quintius*.

In *Nectoquintius*, the calli are conspicuous, transversely raised and uniformly tuberculate, the antennal segment III is slender (Fig. 1), cylindrical and longer than 1.70 mm, the posterocular tubercle is moderately protuberant, the hind femur is not strongly incrassate with only one subapical tooth, the hind tibia is longer than hind femur (Fig. 10), and the posterior angle of connexivum extends into a short, acute spine. In *Quintius* the calli are flat or barely convex and smooth; the antennal segment III is broad (Fig. 4) and shorter than 1.40 mm; the postocular tubercle is not visible, forming smooth curve with eye; the hind femur is incrassate in both sexes (Figs. 10–12), especially in males, ventrally armed with two rows of spines running from middle third to subapical third, and is longer than hind tibia; and the posterior angles of each connexival segment unarmed.

Saguntus is similar to *Nectoquintius* in having the body relatively narrow and elongate, antennal segment III slender, cylindrical and longer than 1.70 mm (Fig. 5), the humeral angles rounded, the posterior angle of each connexival segment extending into short and acute spine, the scutellum longer than wide, and the hind tibiae never dilated. In *Nectoquintius* the triangular processes of the posterior margin of pronotum are narrow and apically subacute, the postocular tubercle is moderately protuberant, the mesosternum lacks a longitudinal median furrow, the calli are transversely raised, the hind femur is not strongly incrassate and has only one subapical tooth, the hind tibiae is longer than hind femur, the male hind tibiae is cylindrical and unarmed (Fig. 10), and the abdominal spiracles are elliptic and



Figures 10–14. Hind leg. Figure 10. *Nectoquintius alajuelensis* new genus, new species (♂). Figure 11. *Quintius dentifer* Stål (♂). Figure 12. *Quintius scenicum* Brailovsky and Barrera (♀). Figure 13. *Saguntus pallens* (Walker) (♂). Figure 14. *Stenoquintius reclusa* new genus, new species (♂).

near to the anterior margin. In *Saguntus* the triangular processes are absent; the postocular tubercle is not visible; the mesosternum has a shallow, median longitudinal furrow; the calli are flat and smooth; the hind femur is incrassate in both sexes, especially in males, ventrally armed with two rows of spines, and longer than hind tibia; the male hind tibiae are curved and armed with one large, ventral spine at midpoint (Fig. 13); and the abdominal spiracles are circular and near to anterior margin.

In caudal view the male genital capsule of *Nectoquintius*, *Quintius*, and *Saguntus* are remarkably different (Figs. 6, 8, 9).

In *Grammopoecilus* Stål the abdomen is tapered inward from the base of pronotum to the apex of abdomen, and the hind tibiae of male are armed distally with ventral and dorsal spines, which are absent in the new genus. In *Nematopus* Berthold, the lateral margins of the abdomen are more or less parallel, the humeral angles are sharp, and the hind femur of male is markedly incrassate and armed with a large curved spine at midpoint of ventral surface, which is absent in the new genus.

Distribution.—Known from Costa Rica and Ecuador.

Etymology.—Masculine: From the Latin “*necto*” (knot) plus the generic name *Quintius*, denoting the relationship between these genera.

NECTOQUINTIUS ALAJUELENSIS BRAILOVSKY AND BARRERA, NEW SPECIES
(Figs. 1, 8, 10, 15)

Types.—Holotype male: Costa Rica. Puntarenas Province, Peninsula de Osa, Rancho Quemado, 200 m, Dic 1992, F. Quesada. Deposited in Instituto Nacional de Biodiversidad, Santo Domingo de Heredia, Costa Rica. Paratypes: 1 female; data: same locality and date as holotype. Deposited in Instituto Nacional de Biodiversidad, Santo Domingo de Heredia, Costa Rica. 1 female: Costa Rica. Alajuela Province, Sector San Ramon de Dos Rios, 620 m, 18 Mar 13 Apr 1995, F. A. Quesada. Deposited in Colección Entomológica del Instituto de Biología, UNAM. 1 male: Costa Rica. Puntarenas Province, Peninsula de Osa, Fila Guerra, 1–100 m, Mar 1991, J. Quesada. Deposited in Colección Entomológica, del Instituto de Biología, UNAM. 2 females: Costa Rica. Puntarenas Province, Parque Nacional Corcovado, Estación Sirena, 0–100 m, Nov 1990 C. Saborio, and Dic 1992, G. Fonseca. Deposited in Instituto Nacional de Biodiversidad, Santo Domingo de Heredia, Costa Rica. 1 male: Costa Rica. Province Alajuela, 20 km S Upala, 10–29 May 1991, F. D. Parker. Deposited in Department of Biology of the Utah State University. 1 female: Costa Rica. San Carlos, collection Schild-Burgdorf. Deposited in the Zoological Department of the Hungarian Natural History Museum. 1 male: Ecuador. Esmeralda Province, Zapallo Grande, 25–30 Oct 1987, M. Huybensz. Deposited in Museum of Comparative Zoology, Harvard University.

Description.—*Male* (holotype). Dorsal coloration: Head yellow tinged with chestnut in front of ocelli; ocellar tubercle brownish; antennal segments I to III bright orange, and IV yellow; pronotal disc bright chestnut orange with collar, frontal angles, posterolateral borders, and middle third of posterior border yellow; calli with yellow and brown marks; anterolateral margins, posterolateral margins (except the border), and posterior border (except middle third) black; scutellum yellow with lateral margins dark brown; clavus and corium dark brown to black with following areas yellow: claval vein, claval commissure, inner corial vein, costal margin and apical margin; hemelytral membrane dark ambarine, with basal angle darker; connexival segments I to V yellow, VI and VII black with anterior third yellow; dorsal abdominal segments dark brown to reddish brown with scars IV–V and V–VI

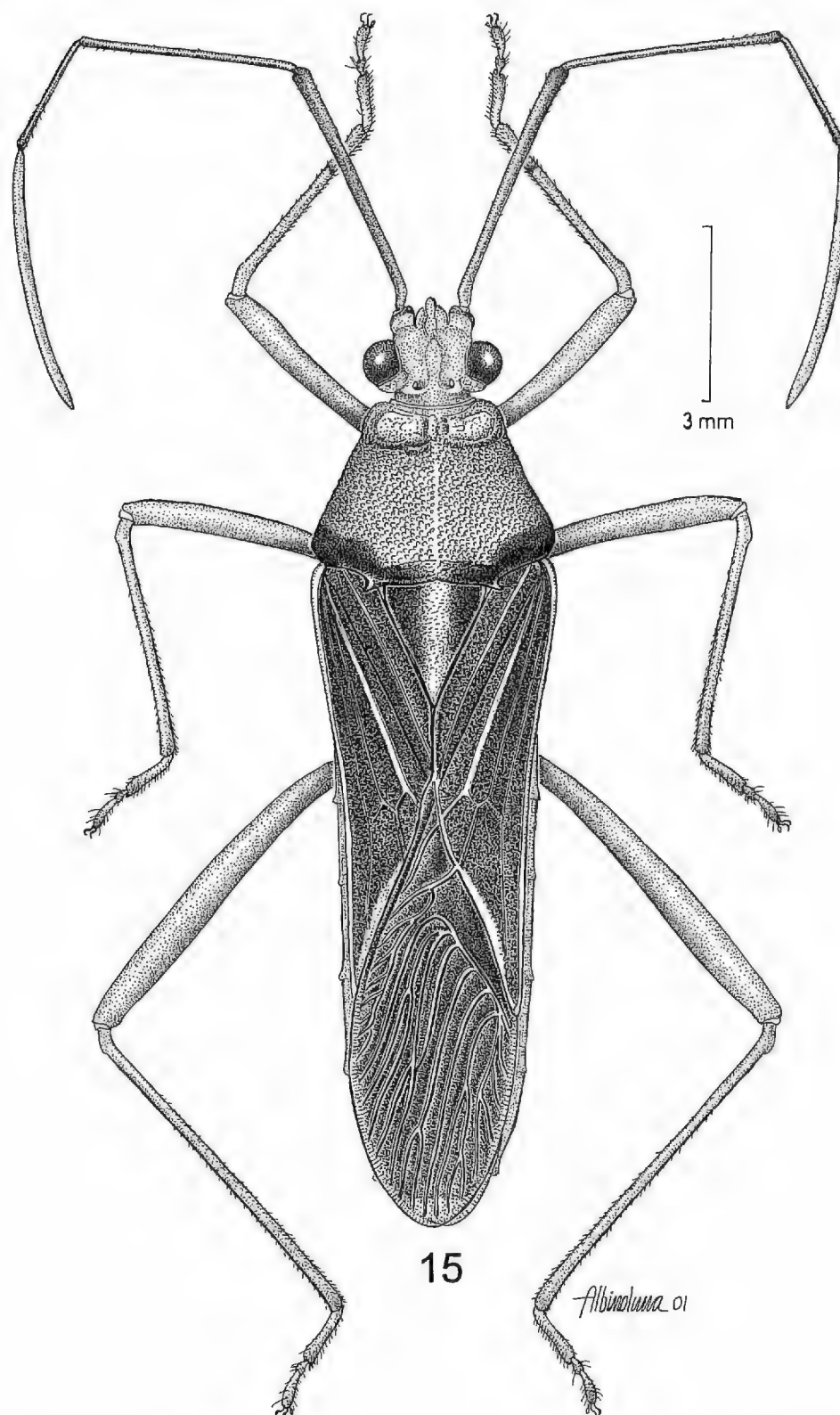


Figure 15. Dorsal view of *Nectoquintius alajuelensis* new genus, new species.

yellow. Ventral coloration: Including rostral segments and legs yellow; apex of rostral segment IV, and caudal surface of genital capsule dark brown; mesopleura and metapleura with narrow and elongate creamy yellow hardened protuberance; metasternum yellow and tinged with orange.

Female.—Coloration: Similar to male holotype. Connexival segments VIII and IX dark brown with anterior angle yellow; dorsal abdominal segments VIII and IX dark brown; genital plates yellow.

Variation.—1, Anterolateral margins of pronotum bright chestnut orange. 2, calli almost entirely yellow. 3, Connexival segment VI with upper margin yellow and inner margin dark brown to reddish brown. 4, Metasternum orange. 5, Pleural abdominal sterna VI and VII yellow with posterior third dark brown.

Measurements.—Male (female). Head length: 1.64 mm (1.84 mm); width across eyes: 2.28 mm (2.32 mm); interocular space: 1.08 mm (1.12 mm); preocular distance: 1.00 mm (1.02 mm); antennal segments lengths: I, 4.20 mm (3.80 mm); II, 3.96 mm (3.76 mm); III, 1.96 mm (1.84 mm); IV 4.76 mm (4.64 mm). Pronotal length: 3.00 mm (3.40 mm); width across frontal angles: 2.64 mm (2.88 mm); width across humeral angles: 4.16 mm (4.80 mm). Maximum length of hind femur: 6.30 mm

(6.10 mm); maximum length of hind tibiae: 6.60 mm (6.60 mm). Scutellar length: 2.24 mm (2.48 mm); width: 1.84 mm (2.08 mm). Total body length: 15.77 mm (17.75 mm).

Etymology.—The name refers to the Alajuela Province of Costa Rica.

STENOQUINTIUS BRAILOVSKY AND BARRERA, NEW GENUS

TYPE SPECIES.—*STENOQUINTIUS MATOGROSSENSIS* BRAILOVSKY AND BARRERA, NEW SPECIES.

Description.—Body medium sized, relatively narrow and elongate. Head: Wider than long, pentagonal, and declivant anteriorly; tylus unarmed, apically globose, raised, extending anterior to and laterally higher than juga; juga unarmed, short, and thickened; antenniferous tubercles broad, widely separated, diverging anteriorly and unarmed; antennal segment I thicker than succeeding segments, and slightly curving; segments II and III cylindrical, and slender; segment IV fusiform; antennal segment IV the longest, III the shortest, and II longer than I (Fig. 3); preocellar pit deep; ocellar tubercle small; eyes hemispherical, prominent; postocular tubercle absent; buccula rounded, short, raised, not projecting beyond antenniferous tubercles, without teeth, and closed posteriorly; rostrum reaching anterior third of mesosternum; genae and mandibular plate unarmed. Thorax. Pronotum: Wider than long, trapeziform, shallowly declivant; collar wide; frontal angles rounded, not exposed; anterolateral borders obliquely straight, weakly nodulose; humeral angles produced laterally into short angulate spine; posterolateral borders sinuate, with outer third nodulose and inner third smooth; posterior border straight; triangular process absent; calli flat to weakly convex, separated along midline by two short longitudinal depressions. Anterior lobe of metathoracic peritreme elongate, reniform, posterior lobe rounded; mesosternum with median and deep sulcus in anterior and posterior third, and faint longitudinal furrow hard to see. Legs: Fore and middle femora not incrassate, ventrally with two rows of short and acute spines; hind femur slightly incrassate (much more in males), and ventrally with two rows of broad and acute spines; fore and middle tibiae unarmed, cylindrical and sulcate; hind tibiae of male longer than hind femur, weakly curved, flattened, armed with large ventral spine close to midpoint, and smaller spines along ventral surface; hind tibiae of female longer or shorter than hind femur, cylindrical, and unarmed (Fig. 14); basal segment of hind tarsi longer than total length of middle and hind segment together. Scutellum: Triangular, flat, longer than wide, with apex subacute. Hemelytra: Macropterous, reaching or extending beyond the apex of the last abdominal segment; costal margin emarginate; apical margin slightly sinuate. Abdomen: Lateral margins parallel; posterior angle of connexivum extending into short and acute spines; abdominal spiracle elliptic, closed to anterior margin; abdominal sterna lacking medial furrow. Integument: Body surface dull, and glabrous; pronotum, clavus, corium, propleura, posterior margin of mesopleura and metapleura, acetabulae, and male genital capsule densely punctate; head, calli, apex of scutellum, connexivum, prosternum, mesosternum, and metasternum, anterior third of mesopleura and metapleura, abdominal sterna and female genital plates impunctate; pubescence of antennal segments, and legs, short, mainly appressed; scutellum transversely striate.

Male Genitalia.—Genital capsule broadly ovoid; posteroventral edge transversely tuberculate or sinuate, with deep circular concavity at midpoint (Fig. 7).

Female Genitalia.—Abdominal sternite VII with plica and fissura; the former curved, reduced, and transversely straight, the latter with inner margin overlapping; gonocoxae I triangular, closed in caudal view, and with upper border rounded; paratergite VIII subtriangular, with spiracle visible; paratergite IX squarish, and larger than paratergite VIII.

Diagnosis.—The relatively narrow and elongate body, the abdominal spiracle elliptic and close to the anterior margin, the ventrally armed femora, the cylindrical tibiae that are never dilated, the longer than wide scutellum, and the mesosternum lacking a longitudinal medial furrow suggests a relationship with *Nectoquintius* described in this paper, and *Quintius* Stål.

In *Stenoquintius*, the antennal segment II is longer than I (Fig. 3), the postocular tubercle and the triangular processes of pronotum are absent, the calli are flat or barely convex, the mesosternum has a deep median, sulcus at anterior and posterior third, the femora are ventrally armed with two rows of spines, and hind

tibiae of male weakly and curved, flattened, and ventrally armed (Figs. 14, 16). In *Nectoquintius*, the antennal segment I is longer than II (Fig. 1), the postocular tubercle is moderately protuberant, the posterior margin of pronotum has the triangular processes narrow, and apically subacute, the are calli transverse and conspicuously raised, the mesosternum lacks an anterior and posterior sulcus, each femur is armed with one subapical small tooth, and hind tibiae of male are cylindrical, slender, and unarmed (Fig. 10). In *Quintius*, like *Stenoquintius*, the postocular tubercle is not visible, the calli are flat or barely convex, and the male hind tibiae are ventrally armed (Figs. 11–12, 14), both the antennal segment III is broad, and shorter than 1.40 mm (Figs. 2, 4), the hind femora, particularly in males, are conspicuously incrassate, the posterior angle of connexival segments are unarmed, and the mesosternum lacks an anterior or posterior sulcus at middle third.

Distribution.—Known from Venezuela and Brazil.

Etymology.—Masculine: From the greek “*stenos*” (narrow), plus the generic name *Quintius*, denoting the relation between both genera.

STENTOQUINTIUS MATOGROSSENSIS BRAILOVSKY AND BARRERA, NEW SPECIES
(Fig. 16)

Types.—Holotype male: Brasil. Mato Grosso, Sinop, Oct 1976, M. Alvarenga. Deposited in American Museum of Natural History, New York. Paratypes: 2 males, 1 female; data: same locality and date as holotype. Deposited in American Museum of Natural History, New York, and Colección Entomológica del Instituto de Biología, UNAM.

Description.—*Male* (holotype). Dorsal coloration: Head pale yellow; antennal segments dark yellow, tinged with green reflections; pronotum yellow, with green reflections, and dark brown punctures at humeral angles, posterolateral margins and posterior margin; scutellum yellow with lateral margins pale orange; clavus and corium yellow with punctures dark brown to chestnut orange; hemelytral membrane ambarine with basal angle darker; connexival segments yellow and VII with upper margin dark brown, basal and apical angle yellow, and inner margin reddish orange; dorsal abdominal segments reddish orange with wide yellow longitudinal stripe running at middle third from I to VI segment. Ventral coloration: Head, prosternum, mesosternum, and metasternum, and abdominal sterna pale yellow; rostral segments (apex of IV dark brown), propleura, mesopleura, and metapleura, acetabulae, legs, pleural margin of abdominal sterna and genital capsule dark yellow, tinged with green reflections, and scattered with red to pink tiny spots; mesopleura and metapleura with wide and broad creamy yellow hardened protuberance.

Genitalia.—Genital capsule. Posteroventral edge transversely sinuate, with deep circular concavity at midpoint.

Female.—Coloration: Similar to the male holotype. Clavus and corium yellow, densely tinged with pink, and with punctures dark brown to chestnut orange; connexival segments I to VI yellow with upper margin tinged with pale brown marks, segment VII like male, and segments VIII and IX yellow with lateral margins brown; propleura, mesopleura, and metapleura with elongate and continuous creamy yellow hardened protuberance; abdominal sterna and genital plates yellow with pleural margins III to VII dirty chestnut brown, scattered with tiny red to pink spots.

Measurements.—Male (female). Head length: 1.28 mm (1.38 mm); width across eyes: 1.96 mm (2.04 mm); interocular space: 0.94 mm (1.00 mm); preocular distance: 0.82 mm (0.96 mm); antennal segments lengths: I, 3.68 mm (3.24 mm); II, 3.84 mm (3.28 mm); III, 2.52 mm (2.24 mm); IV 4.48 mm (4.08 mm). Pronotal length: 3.00 mm (3.60 mm); width across frontal angles: 2.12 mm (2.28 mm); width across humeral angles: 4.00 mm (4.60 mm). Maximum length of hind femur: 5.90 mm (5.80 mm); maximum length of hind tibiae: 6.30 mm (6.00 mm). Scutellar length: 1.84 mm (2.16 mm); width: 1.60 mm (1.92 mm). Total body length: 14.57 mm (15.68 mm).

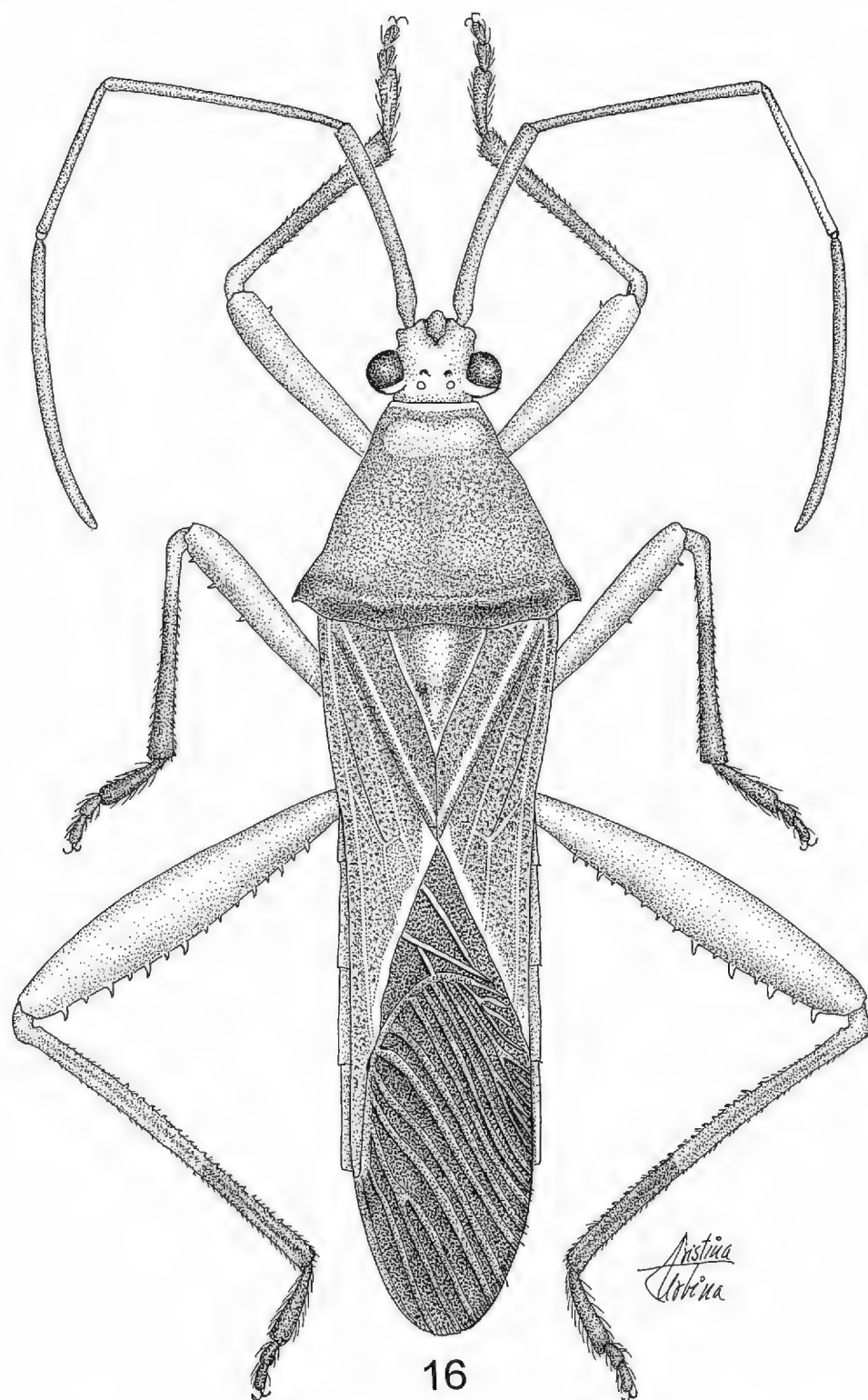


Figure 16. Dorsal view of *Stenoquintius matogrossensis* new genus, new species.

Etymology.—The name is a noun in apposition, referring to the State of Mato Grosso State in Brasil, source of the type series.

STENTOQUINTIUS RECLUSA BRAILOVSKY AND BARRERA, NEW SPECIES
(Figs. 3, 7, 14)

Types.—Holotype male: Venezuela. Territorio Federal Amazonas, San Carlos de Rio Negro, 10 Dic 1984, R. Brown. Deposited in Universidad Central de Venezuela, Facultad de Agronomía, Maracay. Paratypes: 3 males; data: same locality and date as holotype. Deposited in Universidad Central de Venezuela, Facultad de Agronomía, Maracay, and Colección Entomológica, Instituto de Biología, UNAM. 1 male: Venezuela. Territorio Federal Amazonas, San Carlos de Rio Negro, 1 56' N–67 03' W, 6–12 Dic 1984, R.L. Brown. Deposited in Mississippi Entomological Museum, Mississippi State.

Description.—*Male* (holotype). Dorsal coloration: Head pale yellow; antennal segments yellow, tinged with green reflections; pronotum yellow with green reflections and scattered with reddish brown punctures at humeral angles, posterolateral margins and posterior margin; scutellum yellow with lateral margin orange; clavus yellow, tinged with brown, and with the punctures reddish brown; corium yellow with reddish brown punctures; hemelytral membrane ambarine with basal angle darker; connexivum yellow and segment VII with upper border yellow, and inner margin dark brown; dorsal abdominal segments dark brown with yellow longitudinal stripe running at midpoint from I to VI segment. Ventral coloration: Including rostral segments (apex of IV dark brown) and legs yellow, tinged with green reflections; midpoint of mesosternum and metasternum pale yellow with orange reflections; mesopleura and metapleura with broad creamy yellow hardened protuberance; femora, abdominal sterna, and genital capsule pale yellow.

Genitalia.—Genital capsule. Posteroventral edge transversely tuberculate, with deep circular cavity at midpoint (Fig. ??).

Female.—Unknown.

Measurements.—*Male*. Head length: 1.48 mm; width across eyes: 1.84 mm; interocular space: 0.94 mm; preocular distance: 0.94 mm; antennal segments lengths: I, 2.96 mm; II, 2.92 mm; III, 1.88 mm; IV 4.00 mm. Pronotal length: 3.24 mm; width across frontal angles: 1.64 mm; width across humeral angles: 4.08 mm. Maximum length of hind femur: 5.30 mm; maximum length of hind tibiae: 5.20 mm. Scutellar length: 1.88 mm; width: 1.60 mm. Total body length: 14.20 mm.

Discussion.—*Stenoquintius reclusa* can be easily distinguished from *S. mato-grossensis* by the proportions of antennal segments I to IV which are conspicuously shorter (see measurements), the hind femur more incrassate, the hind tibia shorter than hind femur, and by the structure of the posteroventral edge of male genital capsule.

Etymology.—The name “*reclusa*” refers to the secretive habits of this species, which is hard to found on the revised collections.

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**THREE NEW SPECIES OF *SUNDARUS* AMYOT &
SERVILLE, AND KEY TO THE KNOWN SPECIES
(HEMIPTERA: HETEROPTERA: COREIDAE:
COREINAE: COREINI)**

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Abstract.—Three new species of *Sundarus* Amyot and Serville from Brasil, Panama, and Peru are described and illustrated, and a key to the known species of the genus is included.

Key Words.—Insecta, Hemiptera, Heteroptera, Coreidae, Coreini, *Sundarus*, new species, Brasil, Panama, Peru.

Brailovsky (1988) revised the genus *Sundarus* Amyot and Serville, described 13 new species, and discussed the taxonomical importance of the humeral angles and sculpture of the pronotum, the shape of parameres and spermatheca and the general color of the body, including the distributional pattern of the metallic zone. In the same contribution he included a historical review of each species, added new records for the majority of the known species, and gave a key to the known taxa (except to *S. muggei* Schmidt).

Previously, 28 species of *Sundarus* were known. In this contribution, three new species collected in Brasil, Panama, and Peru are described, and a revisioned key to the known species is included (except for *S. muggei* Schmidt).

SUNDARUS OCCUA BRAILOVSKY, NEW SPECIES
(Figs. 2 and 8)

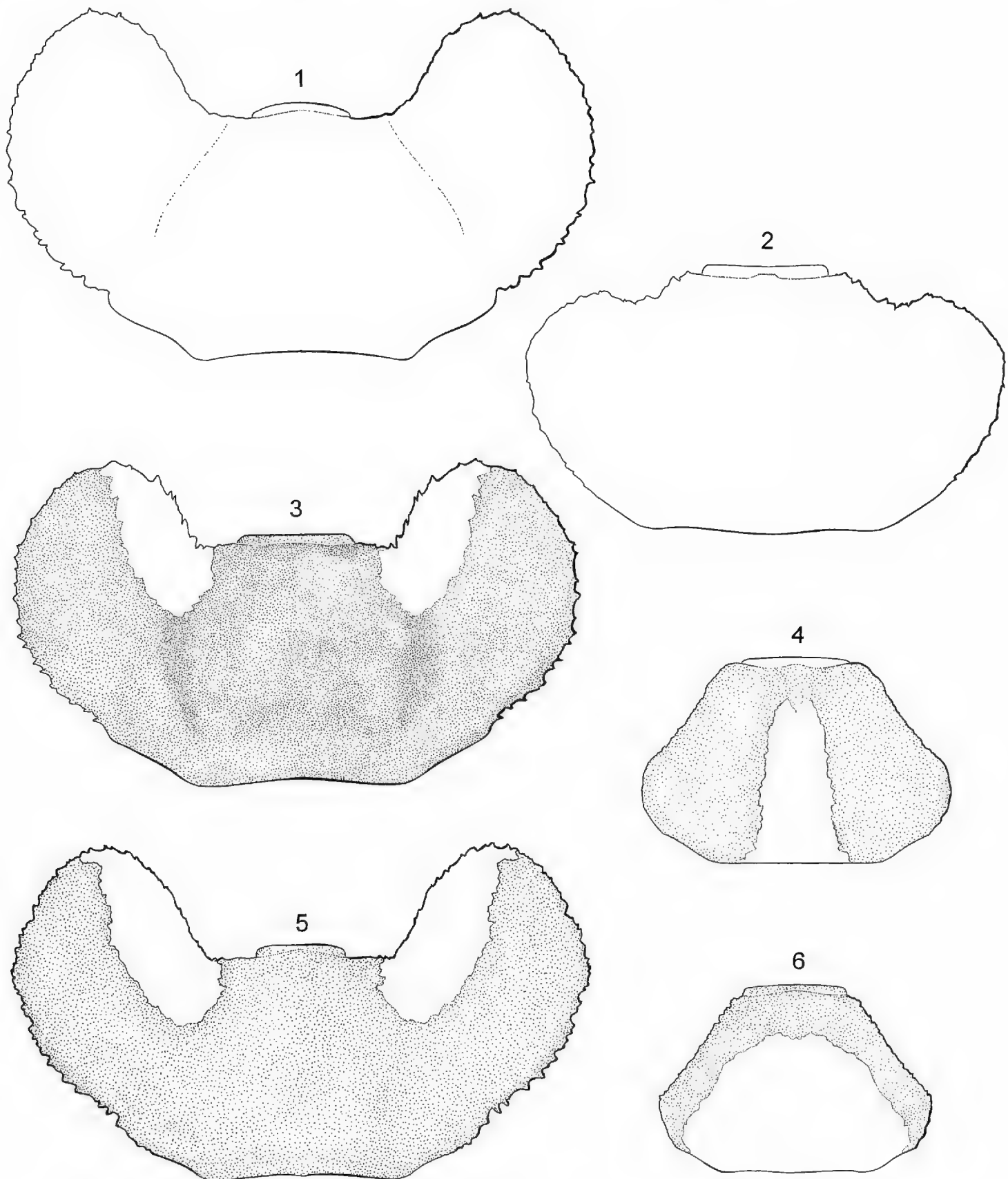
Types.—Holotype female: Panama. Canal Zone, Barro Colorado Isl., Jun 1939, J. Zetek. Deposited in the Colección Entomológica del Instituto de Biología, UNAM, México.

Description.—Female (holotype). Dorsal coloration: Head, pronotum, scutellum, clavus, and corium entirely bright orange; antennal segments I to III reddish brown with blue-green metallic reflections and segment IV reddish brown; hemelytral membrane black; connexivum black with upper margin yellow; dorsal abdominal segments black. Ventral coloration: Head bright orange; rostral segments reddish brown; prosternum, mesosternum, metasternum, anterior and posterior lobe of metathoracic peritreme and adjacent areas black; propleura metallic green with upper margin bright orange; mesopleura and metapleura metallic green with upper border bright orange; legs reddish brown with blue-green metallic reflections; abdominal sterna and genital plates metallic green with pleural margin and posterior border of sterna V to VII yellow. Structure: Head: Rostrum reaching anterior border of metasternum. Pronotum: Anterolateral margins irregularly crenate; humeral angles broad, wider than long, exposed, raised, medium sized, hemispheric, directed upward, and each border crenate; posterolateral and posterior border straight and entire; calli transversely raised (Figs. 2 and 8).

Male.—Unknown.

Measurements.—Female. Head length: 1.56 mm; width across eyes: 2.40 mm; interocular space: 1.32 mm; interocellar space: 0.60 mm; antennal segments lengths: I, 4.08 mm; II, 3.36 mm; III, 3.68 mm; IV, 5.08 mm. Pronotal length: 3.80 mm; maximum width of anterior lobe: 3.20 mm; maximum width of posterior lobe: 6.60 mm; maximum length of humeral angle: 1.52 mm; maximum width of humeral angle: 2.56 mm. Scutellar length: 2.20 mm; width: 2.32 mm. Total body length: 19.28 mm.

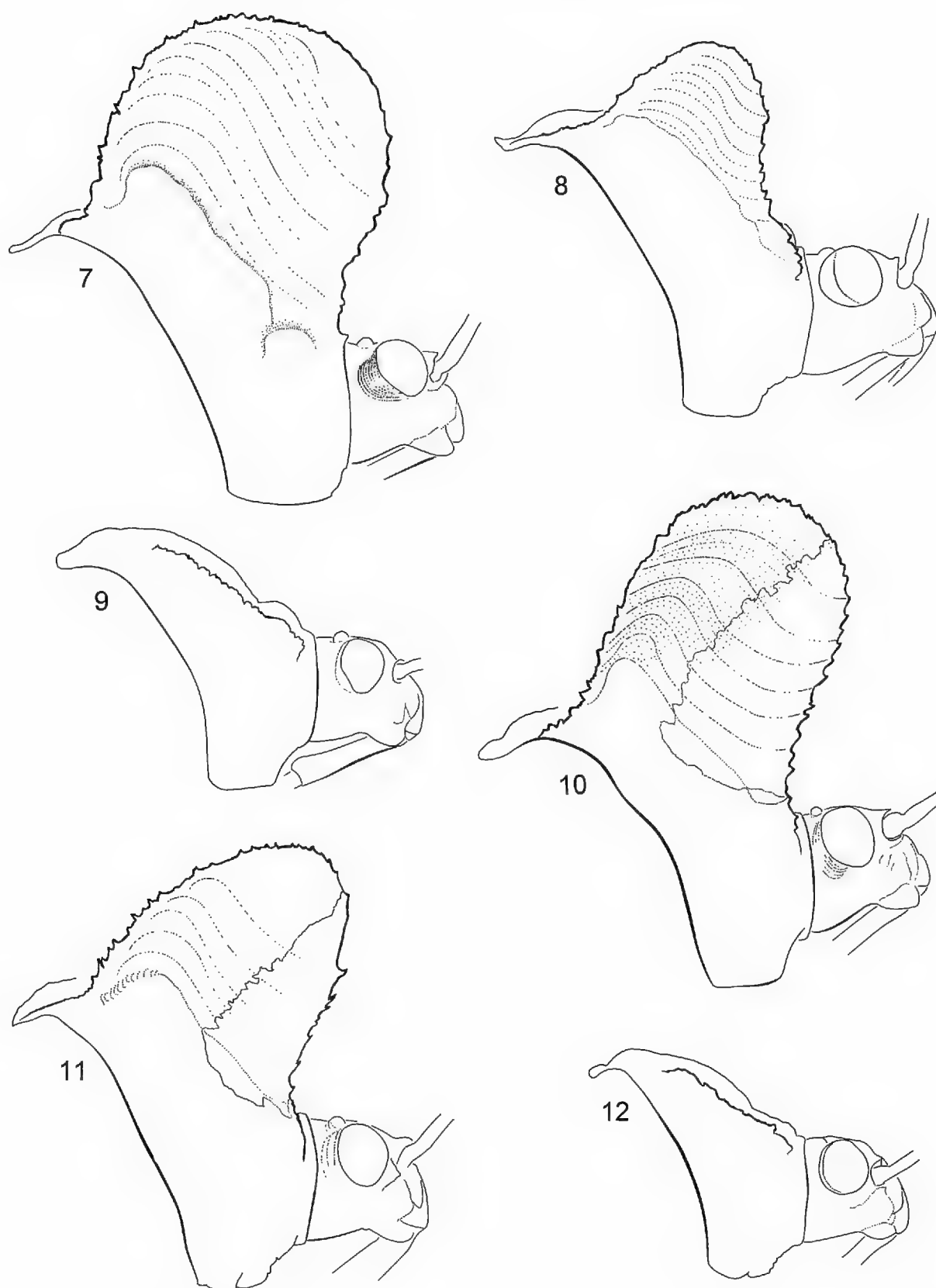
Discussion.—*Sundarus occua* appears to be closely related to *S. ambarinus*



Figures 1–6. Pronotum of *Sundarus* spp., in dorsal view. 1. *S. ambarinus* Brailovsky. 2. *S. occua* Brailovsky, NEW SPECIES. 3. *S. rahmus* Brailovsky, NEW SPECIES. 4. *S. sheilae* Brailovsky. 5. *S. lugens* Horvath. 6. *S. xenia* Brailovsky, NEW SPECIES.

Brailovsky on the basis of the color of pronotum, clavus and corium which are entirely bright orange (*S. occua*) or entirely yellow (*S. ambarinus*). In the other known species of *Sundarus* each region displays extensive black areas.

The most significant difference between the two species lies in the greater expansion of the humeral angles in *S. ambarinus*, where that structure in lateral view almost covers the middle third of the head (Figs. 1 and 7), and by having the thorax entirely yellow. In *S. occua* the humeral expansions are shorter, in lateral view not extending beyond the anterior lobe of the pronotum (Figs. 2 and 8), and the thorax



Figures 7–12. Pronotum of *Sundarus* spp., in lateral view. 7. *S. ambarinus* Brailovsky. 8. *S. occua* Brailovsky, NEW SPECIES. 9. *S. sheilae* Brailovsky. 10. *S. lugens* Horvath. 11. *S. rahmus* Brailovsky, NEW SPECIES. 12. *S. xenia* Brailovsky, NEW SPECIES.

is metallic green with prosternum, mesosternum, metasternum and metathoracic peritreme black, with upper margin of pleural region bright orange.

Etymology.—The species name is an arbitrary combination of letters and is to be treated as a noun.

SUNDARUS RAHMUS BRAILOVSKY, NEW SPECIES

(Figs. 3, 11, 14)

Types.—Holotype male: Peru. San Martin, 6 24' S–76 48' W, 4 Jul 1925, D. Melin. Deposited in Universitets Zoologiska Institut, Uppsala, Sweden. Paratypes:

1 male, 1 female; data: same as holotype. Deposited in Universitets Zoologiska Institut, Uppsala, Sweden and in Colección Entomológica del Instituto de Biología, UNAM, México.

Description.—Male (holotype). Dorsal coloration: Head black with purple metallic reflections; apex of tylus and ocellar tubercle bright to dark orange; inner angle of antenniferous tubercle yellow; antennal segment I red brick, segments II–III reddish brown with blue-green reflections, and segment IV reddish brown; pronotum black with anterolateral margins, anterior third of humeral angles, and short longitudinal stripe running between calli bright orange; collar and calli with blue-green metallic reflections; scutellum bright orange; clavus black with claval commissure creamy yellow; corium black with apical margin creamy yellow and costal border dark orange brown; hemelytral membrane black; connexivum black with upper margin yellow; dorsal abdominal segments black. Ventral coloration: Head reddish brown to black with buccula yellow with bright orange reflections; rostral segment I reddish brown with metallic green reflections, segments II to IV dark reddish brown; propleura black with purple and green metallic reflections, and with upper margin at anterior and middle third bright orange; mesopleura and metapleura black with purple and green metallic reflections; prosternum black; mesosternum and metasternum black with wide longitudinal stripe dark orange on midline; anterior lobe of metathoracic peritreme and adjacent areas black, posterior lobe bright orange; legs brick red; trochanters and femora with blue-green metallic reflections; middle third of abdomen black to dark reddish brown and laterally with three longitudinal rows of colors, each one clearly separated, the inner one metallic green, next metallic purple and the outer included pleural margin yellow; genital capsule black with green metallic reflections, and with posteroventral edge bright orange. Structure: Rostrum reaching posterior margin of metasternum. Pronotum: Anterolateral margins irregularly crenate; humeral angles broad, wider than long, conspicuously exposed, raised, large sized, hemispheric, directed upward, each border crenate, and in lateral view almost reaching the middle third of head (Figs. 3 and 11); posterolateral and posterior border straight, entire; calli transversely flat or slightly raised. Genital capsule: Posteroventral edge simple, with wide central concavity.

Female.—Coloration: Similar to male. Antennal segments I to III red brick and IV reddish brown; collar and calli clearly with blue-green metallic reflections; connexival segments VIII and IX black with upper margin dark yellow; abdominal segments VIII and IX black; gonocoxae I black with blue-green reflections; paratergites VIII and IX black.

Measurements.—Male (female). Head length: 1.72 mm (1.80 mm); width across eyes: 2.16 mm (2.32 mm); interocular space: 1.12 mm (1.22 mm); interocellar space: 0.42 mm (0.52 mm); antennal segments lengths: I, 4.24 mm (4.40 mm); II, 3.44 mm (3.16 mm); III, 3.52 mm (3.56 mm); IV, 5.40 mm (5.20 mm). Pronotal length: 3.44 mm (3.88 mm); maximum width of anterior lobe: 2.40 mm (2.64 mm); maximum width of posterior lobe: 7.30 mm (7.60 mm); maximum length of humeral angle: 2.76 mm (2.92 mm); maximum width of humeral angle: 3.08 mm (3.36 mm). Scutellar length: 2.00 mm (2.36 mm); width: 2.04 mm (2.52 mm). Total body length: 17.98 mm (20.15 mm).

Discussion.—Like *S. lugens* Horvath, with humeral angles of pronotum produced anteriorly into wing-like projections (Figs. 3, 5, 10–11), always bicolorous, with posterior third black, and with head in dorsal view black to reddish brown and always with metallic reflections.

In *S. rahmus*, the anterior lobe of metathoracic peritreme and adjacent areas are black with posterior lobe bright orange, and abdominal sterna are black to reddish brown with three rows of colors clearly separated. In *S. lugens*, the anterior and posterior lobe of metathoracic peritreme and adjacent areas are pale orange, and the color of the abdominal sterna exhibit a pink metallic reflection, with only the pleural margin yellow.

Etymology.—The species name is an arbitrary combination of letters and is to be treated as a noun.

SUNDARUS XENIA BRAILOVSKY, NEW SPECIES

(Figs. 6, 12–13)

Types.—Holotype male: Brasil. Rondonia, 62 km., SW Ariquemes, nr Fzda Rcho. Grande, 4–16 Nov 1997, J. E. Eger. Deposited in United States National

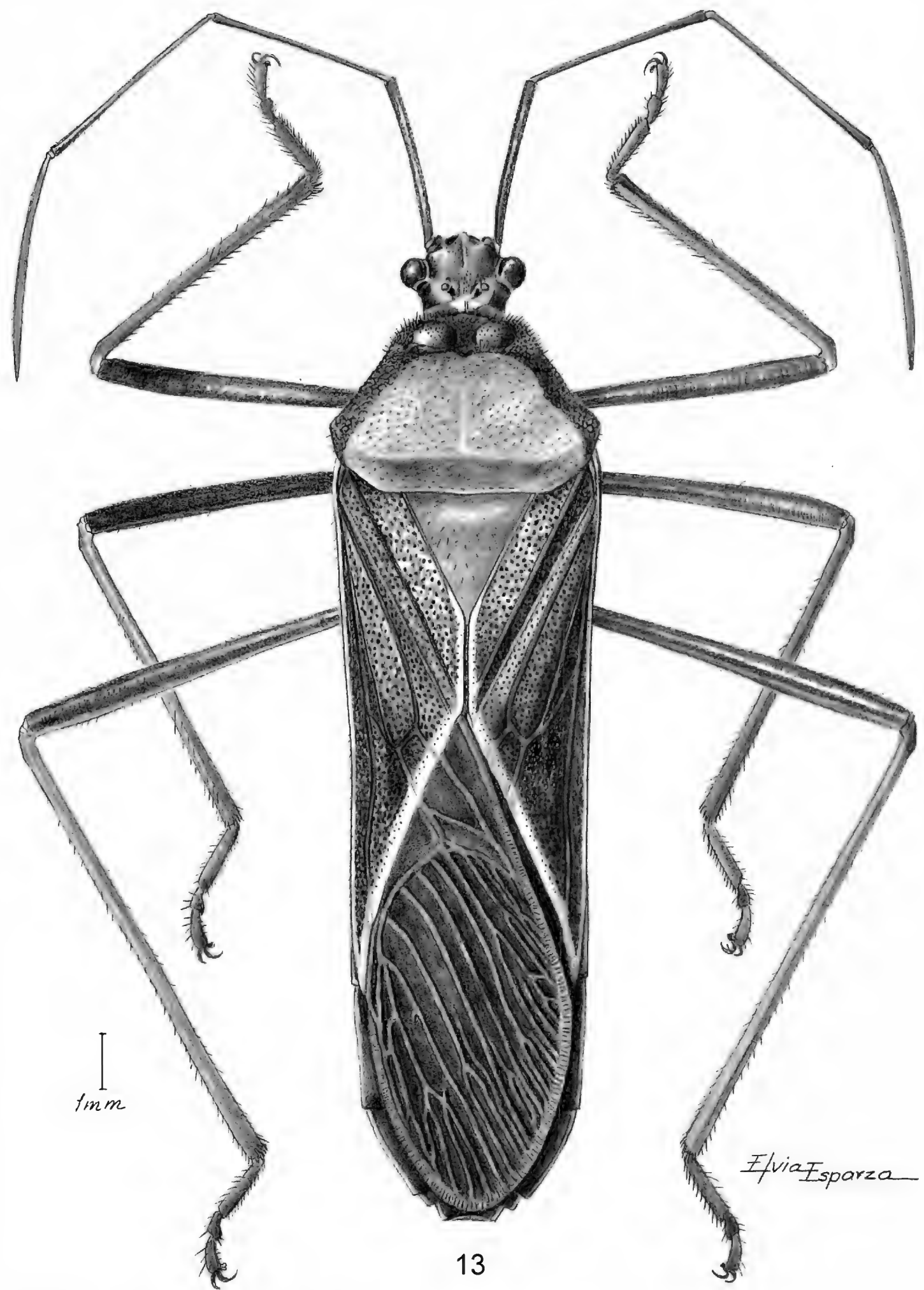


Figure 13. Dorsal view of *Sundarus xenia* Brailovsky, NEW SPECIES.

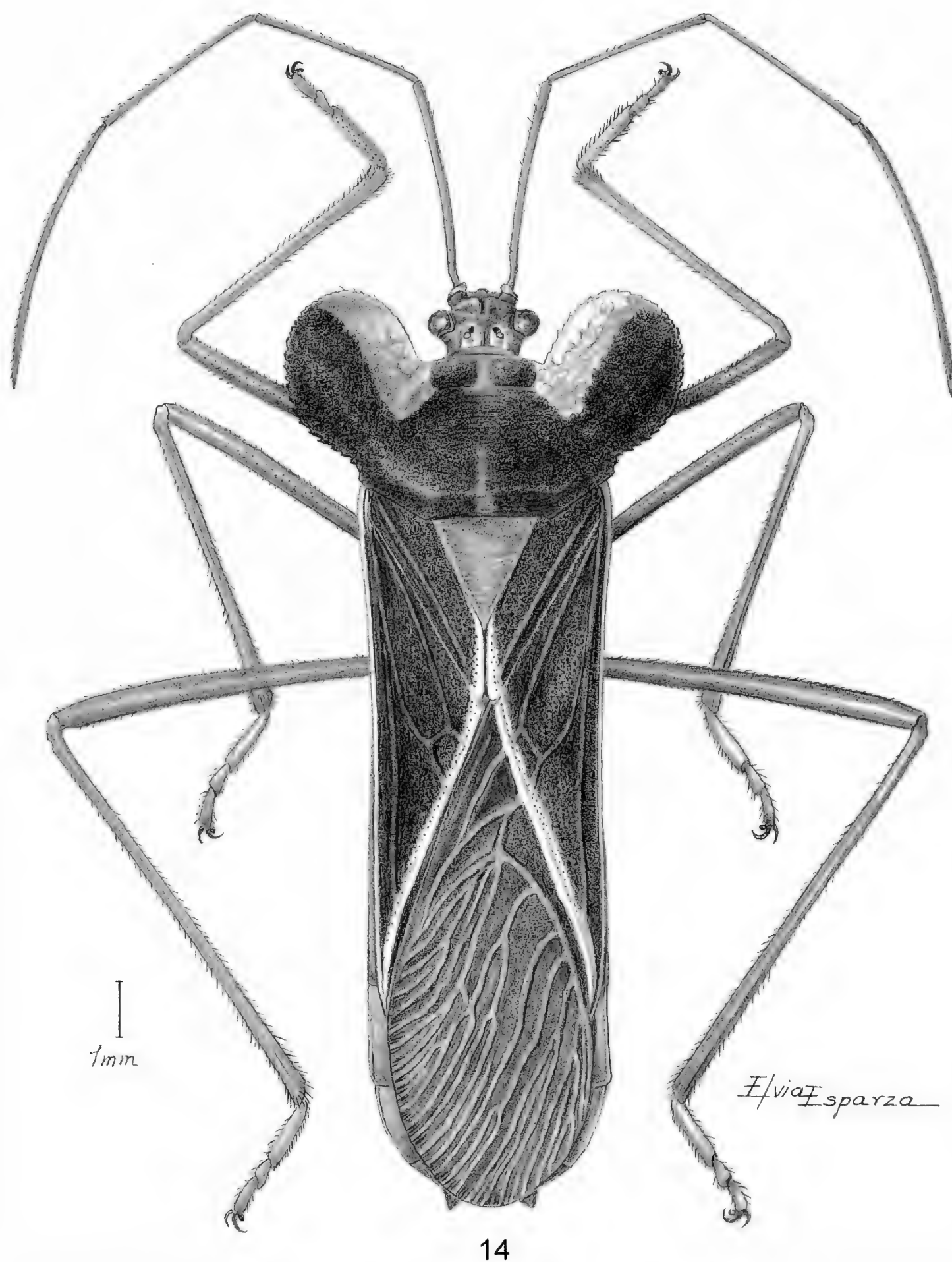


Figure 14. Dorsal view of *Sundarus rahmus* Brailovsky, NEW SPECIES.

Museum of Natural History, Washington, D. C. (Drake Collection). Paratypes: 3 males, 4 females; data: same as holotype: 30 Mar–10 Apr 1992, J. E. Eger, and 5 Dec 1991, S. L. Heydon. Deposited in Colección Entomológica del Instituto de Biología, UNAM, México; United States National Museum of Natural History, Washington, D. C. (Drake Collection); and Department of Entomology, University

of California, Davis, California. 1 male; data: Brasil. Rondonia, vic. Caucalandia, 0 32' S–62 48' W, 160–350 m, 14 Oct 1991, J. R. MacDonald. Deposited in Mississippi Entomological Museum, Mississippi State. 1 female; data: Brasil. Rondonia, 10 km S of Caucalandia (Linea C5) off B-65, 19–21 Mar 1991, B. Kondratieff. Deposited in Colorado State University, Department of Entomology, Fort Collins, Colorado. 1 female; data: Peru. Rio Taiche, 1923, H. Bassler. Deposited in American Museum of Natural History, New York.

Description.—Male (holotype). Dorsal coloration: Head metallic green with apex of tylus, inner angle of antenniferous tubercle and ocellar tubercle dark yellow; antennal segments I to III black with blue-purple metallic reflections, and segment IV reddish brown; pronotum metallic green with wide bell-shaped orange spot at posterior lobe and below calli; scutellum orange; clavus and corium black with blue and purple metallic reflections and with claval commissure, apical margin and costal border creamy yellow; hemelytral membrane black; connexivum black with upper margin yellow; dorsal abdominal segments black, except segment VI with blue-purple metallic reflections. Ventral coloration: Head metallic green; buccula orange with green metallic reflections; rostral segments dark reddish brown with blue-green metallic reflections at segments I and II; thorax metallic green with anterior and posterior lobe of metathoracic peritreme and adjacent areas orange; prosternum and mesosternum reddish brown with median longitudinal stripe dark orange; metasternum reddish brown; abdominal sterna metallic green with pleural margin yellow; genital capsule metallic pink with green metallic reflections and with postero ventral edge yellow; coxae, trochanters and femora dark reddish brown with blue-green metallic reflections; tibiae dark brick red with blue-green metallic reflections and tarsi dark brick red. Structure: Rostrum reaching posterior margin of metasternum. Pronotum: Anterolateral margins obliquely straight, scarcely crenate; humeral angles not exposed, truncated with borders sinuate (Figs. 6 and 12); posterolateral and posterior border straight and entire; calli transversely raised. Genital capsule. Posteroventral edge simple, broadly concave.

Female.—Coloration: Similar to male. Connexival segments VIII and IX black with blue-green reflections; abdominal sterna metallic green with pink metallic reflections, and with pleural margin yellow; gonocoxae I metallic pink; paratergite VIII and IX black with green metallic reflections, and with upper margin yellow.

Measurements.—Male (female). Head length: 1.46 mm (1.84 mm); width across eyes: 2.08 mm (2.36 mm); interocular space: 1.08 mm (1.34 mm); interocellar space: 0.47 mm (0.54 mm); antennal segments lengths: I, 3.28 mm (3.60 mm); II, 3.12 mm (3.40 mm); III, 3.40 mm (3.68 mm); IV, 4.64 mm (5.04 mm). Pronotal length: 2.80 mm (4.12 mm); maximum width of anterior lobe: 2.08 mm (3.20 mm); maximum width of posterior lobe: 3.84 mm (5.60 mm). Scutellar length: 1.76 mm (2.20 mm); width: 1.60 mm (2.32 mm). Total body length: 14.65 mm (20.97 mm).

Discussion.—The pronotal shape, including the humeral angles not exposed and truncated (Figs. 6 and 12), the pronotum and thorax not entirely yellow, the pronotal disk not bulging outwards, and rostral segment I reddish brown and never yellow, somewhat similar to *S. sheilae* Brailovsky. *Sundarus xenia* described from Brazil is recognized by having an orange bell-shaped spot covering most of the posterior lobe of pronotal disk (Figs. 6, 12–13). In *S. sheilae*, only recorded from Bolivia, the posterior lobe of pronotal disk is metallic green with an orange longitudinal and relatively narrow rectangular-shape median stripe (Figs. 4 and 9).

Etymology.—The species name is an arbitrary combination of letters and is to be treated as a noun.

KEY TO *SUNDARUS* SPECIES**

1. Humeral angles of pronotum blunt, obtuse, not exposed or barely laminated (Figs. 4, 6, 9, 12) 2

** *S. muggei* Schmidt is excluded from the key.

- 1'. Humeral angles of pronotum produced into wing-like projections (Figs. 1, 3, 5, 7, 10–11) 8
2. Pronotum and thorax entirely yellow *S. splendidus* Distant
- 2'. Pronotum and thorax not entirely yellow 3
3. Pronotum metallic purple; anterior third of pronotal disk strongly convex, with calli sunken; rostral segment I yellow *S. gibbus* Brailovsky
- 3'. Pronotum not metallic purple; pronotal disk not remarkably convex; rostral segment I black to reddish brown 4
4. Pronotum entirely metallic blue-green *S. castus* Brailovsky
- 4'. Pronotum not entirely metallic blue-green 5
5. Pronotum metallic green with an orange spot at posterior lobe 6
- 5'. Pronotum not metallic green with an orange spot 7
6. Posterior lobe of pronotum with an orange bell-shaped spot covering most of disk (Fig. 6) *S. xenia* Brailovsky, NEW SPECIES
- 6'. Posterior lobe of pronotum with orange but narrow rectangular-shaped stripe on middle third (Fig. 4) *S. sheilae* Brailovsky
7. Pronotum black, with anterolateral margins and collar yellow, and calli and adjacent region metallic green *S. ducalis* (in part)
- 7'. Pronotum metallic green and posteriorly with two broad black spots lateral to middle line *S. rufoscutellatus* (Gray)
8. Clavus and corium entirely yellow or bright orange 9
- 8'. Clavus and corium always with black areas 10
9. Pronotum, clavus and corium entirely yellow; humeral angles of pronotum in lateral view almost covering the middle third of head (Fig. 7); thorax entirely yellow *S. ambarinus* Brailovsky
- 9'. Pronotum, clavus and corium entirely bright orange; humeral angles of pronotum shorter, in lateral view not extending beyond anterior lobe (Fig. 8); thorax almost entirely metallic green and never yellow *S. occua* Brailovsky, NEW SPECIES
10. Wing projections of pronotum bicolourous (Figs. 3 and 5) 11
- 10'. Wing projections of pronotum unicolourous, usually yellow or orange and eventually with metallic green reflections at posterior margin 17
11. Head dorsally yellow or orange without metallic reflections *S. regalis* (Westwood)
- 11'. Head dorsally with green, blue or purple metallic reflections. 12
12. Posterior lobe of pronotal disk entirely yellow or at least with broad or narrow longitudinal yellow stripe at middle third 13
- 12'. Posterior lobe of pronotal disk black or metallic blue-green, and never with yellow or orange marks 14
13. Posterior lobe of pronotal disk entirely yellow; wing-like projection remarkably expanded, in lateral view extending beyond the apex of tylus; calli yellow; black spot of wing-like projection surrounded by yellow *S. vulneratus* Brailovsky
- 13'. Posterior lobe of pronotal disk black with yellow longitudinal stripe at mid point; wing-like projection shorter, in lateral view not extending beyond the anterior third of eyes; calli metallic green; posterior lobe of wing-like projection entirely black *S. collinus* Brailovsky

14. Pronotal disk behind calli with blue-green-purple metallic reflections ..
..... *S. zonatus* Brailovsky
- 14'. Pronotal disk behind calli black without metallic reflections. 15
- 15'. Pronotal collar yellow; humeral angles of pronotum barely expanded ..
..... *S. ducalis* (Stål) (in part)
- 15'. Pronotal collar metallic green; wing-like projections conspicuously expanded (Figs. 3, 5, 10–11) 16
16. Anterior lobe of metathoracic peritreme and adjacent areas black
..... *S. rahmus* Brailovsky, NEW SPECIES
- 16'. Anterior lobe of metathoracic peritreme and adjacent areas pale orange
..... *S. lugens* Horvath
17. Scutellum black *S. acutus* Signoret
- 17'. Scutellum yellow or orange 18
18. Anterior and posterior lobe of metathoracic peritreme and adjacent areas black to reddish brown *S. nigrosteolatus* Brailovsky
- 18'. Anterior and posterior lobe of metathoracic peritreme yellow or orange without black areas 19
19. Head dorsally yellow or orange without metallic reflections 20
- 19'. Head dorsally with green or pink metallic reflections 25
20. Wing-like projections of pronotum longer than wide 21
- 20'. Wing-like projections of pronotum wider than long or subequal 23
21. Wing-like projections rectangular, conspicuously expanded, in lateral view extending beyond the apex of tylus *S. selvaticus* Brailovsky
- 21'. Wing-like projections medium sized, acute or rounded, in lateral view reaching the eyes 22
22. Mesothorax and metathorax entirely orange; wing-like projections rounded *S. flavicollis* Signoret
- 22'. Mesothorax and metathorax metallic green with pink reflections; wing-like projections rectangular *S. tropicalis* Brailovsky
23. Prothorax metallic green with propleural expansions and posterior margin orange *S. perpictus* Distant
- 23'. Prothorax yellow with acetabulae metallic green 24
24. Wing-like projections, conspicuously rounded *S. paludum* Brailovsky
- 24'. Wing-like projections shorter and slightly more elongate than rounded
..... *S. horni* Schmidt
25. Thorax entirely yellow or orange *S. inca* Breddin
- 25'. Thorax metallic green with or without pink reflections 26
26. Posterior margin of prothorax entirely yellow or orange 27
- 26'. Posterior margin of prothorax metallic green or only with the border yellow but never covering entire margin 28
27. Pronotum entirely yellow or orange *S. volutatorius* Brailovsky
- 27'. Pronotum with collar and calli metallic green *S. bellus* Brailovsky
28. Calli yellow or orange *S. mucronatus* Horvath
- 28'. Calli metallic green, with or without pink reflections 29
29. Anterior lobe of pronotal disk entirely metallic green
..... *S. humeralis* Horvath
- 29'. Anterior lobe of pronotal disk entirely yellow or orange 30

30. Wing-like projections remarkably expanded, in lateral view extending beyond apex of tylus *S. palmatus* Schmidt
30'. Wing-like projections shorter, in lateral view reaching the middle third of eyes *S. pontifex* Buchana White

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Scientific Note

DISCOVERY OF *BRUCHIDIUS VILLOSUS* F. (COLEOPTERA: BRUCHIDIDAE) ON SCOTCH BROOM IN CANADA

Scotch broom (*Cytisus scoparius* (L.) Link [Fabaceae]) is an invasive leguminous shrub native to continental Europe (Waloff, N. 1966. J. Appl. Ecol. 3: 293–311). Scotch broom has now been disseminated to temperate regions of the world with movements of people. In North America it was introduced as a garden or ornamental hedge species and has since spread far beyond the bounds of cultivation in all locations (Zielke, K., J. O. Boateng, N. Caldicott & H. Williams. 1992. Broom and gorse in British Columbia: a forestry perspective problem analysis. Ministry of Forests, Victoria, British Columbia) and is now distributed along both the Atlantic and Pacific Coasts. Scotch broom had become naturalized in British Columbia and in initial surveys was found on southern Vancouver Island, the Lower Mainland, and the Gulf Islands as far north as Cortes, Hernando, Savary and Texada Islands (Taylor, T. M. C. 1974. The pea family of British Columbia. British Columbia Provincial Museum Handbook No. 32, Victoria, British Columbia). More recent spread has been reported to the northern limit of Vancouver Island and into the Queen Charlotte Islands (Zielke, K., J. O. Boateng, N. Caldicott & H. Williams. 1992. Broom and gorse in British Columbia: a forestry perspective problem analysis. Ministry of Forests, Victoria, British Columbia). Scotch broom is also occurs on the Sunshine Coast to Powell River, through the Fraser and Chilliwack Valleys, into Hope, in the west Kootenay region in the British Columbia interior, and between Nelson and Castlegar (Zielke, K., J. O. Boateng, N. Caldicott & H. Williams. 1992. Broom and gorse in British Columbia: a forestry perspective problem analysis. Ministry of Forests, Victoria, British Columbia). Several European broom specialist insects are known from broom in western North America; *Aceria genistae* Nalepa (Acari: Eriphyidae), *Agonopterix nervosa* Haworth (Lepidoptera: Oecophoridae), *Arytainilla spartiophila* Förster (Hemiptera: Psyllidae), (*Ctenocallis setosa* Kaltenbach (Homoptera: Aphididae), *Gargara genistae* F. (Hemiptera: Membracidae), *Dictyonota fuliginosa* (Costa) (Hemiptera: Tingidae), *Leucoptera spartefolliella* (Hübner) (Lepidoptera: Lyonetiidae), and three species of mirids (Chan, K. L. & C. E. Turner. 1998. Pan-Pacific. Entomol., 74(1): 55–57; Andres, L. A. & E. M. Coombs. 1995. Scotch broom. In Nechols, J. R.; L. A. Andres; J. W. Beardsly; R. D. Goeden; and C. G. Jackson (eds.). Biological control in the western United States: accomplishments and benefits of regional research project W-84. Berkeley, California, United States of America, University of California, Division of Agriculture and Natural Resources, Pub. No. 3361, pp. 303–305; Pfeiffer, D. G. 1986. J. Entomol. Sci., 21(3): 214–218; Waloff, N. 1966. J. Appl. Ecol., 3: 293–311; Downes, W. 1957. Entomol. Soc. B. C., 54: 11–13; Footit, R. G. & W. R. Richards. 1993. The insects and arachnids of Canada. Part 22: The genera of aphids in Canada (Homoptera: Aphidoidea and Phylloxeroidea), Agriculture Canada, Ottawa; Syrett, P., S. V. Fowler, E. M. Coombs, J. R. Hosking, G. P. Markin, Q. Paynter & A. W. Sheppard. 1999.

Biocontrol News Inf., 20: 17N–34N). No biological control agents have been intentionally introduced as part of a biological control program for Scotch broom in Canada. We report here the discovery of another accidentally introduced insect specialist *Bruchidius villosus* F. (Coleoptera: Bruchidae) on Scotch broom in the vicinity of Victoria, British Columbia.

The Scotch broom seed-feeding beetles were discovered in a seed collection conducted in mid-July 2000. Pods were collected from approximately 50 plants over a one-hectare area on a power line right-of-way that intersects Munn Road, Victoria (48°31'00'' N, 123°26'00'' W, elevation 81 m). The site is within the coastal Douglas-fir biogeoclimatic zone on a rock outcrop dominated by *C. scoparius*, *Quercus garryana*, *Holodiscus discolor*, and grass species. After collection, mature seeds were removed from pods and placed in vials for storage. In early August 2000, sixty-six *B. villosus* had emerged from the seeds through small holes. Examination of the remaining seeds revealed that the seeds infested with beetles had darkened noticeably since collection. Within 10 days the 416 beetles had emerged (51 failed to emerge) from a total of 1179 seeds (approximately 100 pods).

The beetles were subsequently identified by J. M. Kingsolver of the Florida State Collections of Arthropods as *Bruchidius villosus* F. (Coleoptera: Bruchidae), described from Scotch broom (*Sarothamnus scoparius* Koch. [= *Cytisus scoparius* (L.) Link]) by B. J. Southgate (Southgate, B. J. 1963. Ann. Entomol. Soc. Am., 56: 795–797). It is unknown how or when these bruchids arrived in British Columbia. This is the first record of *B. villosus* in British Columbia.

In Europe, *Bruchidius villosus* is restricted to Scotch broom and the adults only oviposit in the presence of a broom pod (Parnell, J. R. 1966. J. Anim. Ecol. 35: 157–188). Its native range includes the U.K., France, Portugal, Spain, Austria, Denmark, Germany, Hungary, Italy, and Switzerland (Frick, K. E. 1962 Unpublished file report, USDA—Agricultural Research Service; Syrett, P. & K. E. Emberson. 1997. Biocontrol Sci. Technol., 7(3): 309–326). *B. villosus* has been intentionally introduced in Australia and New Zealand where broom has also become naturalized. Small numbers of *B. villosus* were released in the United States in 1998 in the foothills of the Cascades and on the Oregon coast. To date there have been no recoveries of *B. villosus* from the coastal 1998 release site, however, given the low number of adults (130) released, it is not surprising and is not considered a failed release. *B. villosus* was released at 18 sites in Oregon and Washington State in 1999. The beetle was recovered at two 1999 release sites inspected in 2000. There are now more than 30 releases on Scotch broom and one each on French and Portuguese broom (D. Isaacson, personal communication). In 2001, an informal survey was conducted to determine the distribution of *B. villosus* on Scotch broom in British Columbia. *B. villosus* was found at 31 of 32 sites on Vancouver Island from 48°25' N to 50°01' N and at nine of 11 sites on the mainland from 49°02' N to 49°54' N. Seed damaged varied from 1% to 87% depending upon site. Based on my observations that *B. villosus* is common and widespread on Scotch broom in British Columbia, it seems unlikely that bruchids released in the Pacific Northwest of the United States are the source of the Canadian populations. *B. villosus* was first recorded on Scotch broom in Massachusetts in 1918 after an accidental introduction (Bottimer, L. J. 1968. Can. Ent., 100: 139–145). One could postulate that *B. villosus* has spread from Mas-

sachusetts site to western Canada, utilizing other legumes as hosts in the absence of Scotch broom, however, given the host specificity of *B. villosus*, this is unlikely (Parnell, J. R. 1966. *J. Anim. Ecol.*, 35: 157–188). Another hypothesis is that *B. villosus* was independently introduced into British Columbia after 1963 when Waloff (Waloff, N. 1966. *J. Appl. Ecol.*, 3: 293–311) reported that there were no insects living inside the broom pods.

Additional collections of Scotch broom pods will be made next season to determine the range and infestation levels of this species in British Columbia as well as its potential for control of the spread of Scotch broom.

Records.—BRITISH COLUMBIA, VICTORIA: Munn Road, 18 July 2000, L. R. E. Hooper, *Cytisus scoparius*, seeds.

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Scientific Note

PRELIMINARY INSECT SURVEY ON WESTERN POISON OAK (*TOXICODENDRON DIVERSILOBUM* (TORREY & GRAY)), COYOTE BRUSH (*BACCHARIS PILULARIS* DE CONDOLLE), AND TOYON (*HETEROMELES ARBUTIFOLIA* (LINDLEY)) IN THE SANTA CRUZ MOUNTAINS, CALIFORNIA

Chaparral represents one of the most widespread and unique vegetation types in California, covering roughly 9% of the state (Holland, V. L. & D. J. Keil, 1995, California vegetation. Kendall/Hunt Publishing, Dubuque, Iowa), yet little documentation exists on the diversity of insects found within this community. Agricultural and urban expansion, grazing, fire suppression, and the introduction of exotic plants all threaten chaparral habitat. Over a one year period beginning June 1995, we examined the insect fauna present on three commonly encountered shrubs within a chaparral community: western poison oak (*Toxicodendron diversilobum* (Torrey & Gray)), coyote brush (*Baccharis pilularis* De Condolle), and toyon (*Heteromeles arbutifolia* (Lindley)). Our objective was to develop a preliminary inventory of the insect fauna for the chaparral community in the central region of California and forms the basis of this scientific note.

Sampling was done in the Santa Cruz Mountains in portions of Santa Clara, Santa Cruz, and San Mateo counties in Northern California. Locations were randomly selected and used in this study if the three shrub species were present in quantities sufficient for sampling within a range of approximately 1 km. Nine new locations were sampled for each period. There were eight sampling periods throughout the year with five weeks between the start of periods except for two ten-week intervals during the winter. All sampling was done during the day in dry weather.

At each location, beating samples were taken from each species of shrub, from ten healthy branches of each species. The ten branches were selected to give a fairly uniform distribution across the patch of shrubs within the sampling location; branches close to other plant species were avoided. Branches were beaten with a length of broomstick over a 0.5 m² linen beating tray-funnel and dislodged material collected in a large jar. Samples were kept in plastic bags and frozen before sorting arthropods from debris.

Several resources were used for specimen identification, including specialists, identification keys, and by comparison with specimens in the collections at the California Academy of Sciences and San Jose State University. Due to lack of resources and time, identification efforts concentrated on the most common species, leaving many species undetermined. Undetermined species were separated by morphology. Voucher specimens have been deposited at the J. Gordon Edwards Museum at San Jose State University. A listing of the 826 insect species collected can be found in Appendix 1.

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Appendix 1. Number of insect specimens collected from coyote brush (C), poison oak (P), and toyon (T) over a 1 year period. Unless specified otherwise, Lepidoptera and Neuroptera are larvae and insects in other orders are adults.

Order	Family	Species	C	P	T
Collembola					
	Hypogastruidae	undet. sp. 1	4	0	4
		undet. sp. 2	2	0	0
	Isotomidae	undet. sp. 1	0	2	0
		undet. sp. 2	0	0	1
		undet. sp. 3	3	2	2
		undet. sp. 4	0	0	1
		undet. sp. 5	0	1	0
		undet. sp. 6	0	0	1
	Entomobryidae	<i>Entomobrya atrocincta</i> Schött	16	2	6
		<i>Entomobrya multifasciata</i> (Tullberg)	447	32	35
		<i>Entomobrya suzannae</i> Schött	11	16	46
		undet. sp. 1	4	0	8
		undet. sp. 2	1	0	0
		undet. sp. 3	0	0	4
		undet. sp. 4	0	1	1
	Sminthuridae	<i>Bourletiella</i> n. sp. 1	61	153	9
		<i>Bourletiella</i> n. sp. 2	489	364	277
		<i>Bourletiella</i> sp. 3	0	62	0
		<i>Dicyrtoma beta</i> Christiansen & Bellinger	179	68	192
		<i>Sminthurus</i> sp.	1	0	1
Microcoryphia					
	Machilidae	undet. sp. 1	1	0	0
		undet. sp. 2	0	1	0
Thysanura					
	Lepismatidae	undet. sp.	1	0	0
Ephemeroptera					
	Undetermined	undet. sp. 1	0	1	0
		undet. sp. 2	0	0	1

Appendix 1. Continued.

Order Family	Species	C	P	T
Phasmida				
Timemidae	<i>Timema californica</i> Scudder	20	1	115
Orthoptera				
Acrididae	undet. sp. 1	1	0	0
	undet. sp. 2	1	0	0
Tettigoniidae	<i>Microcentrum</i> sp.	2	2	2
	undet. sp. 2	0	1	0
	undet. sp. 3	0	1	0
	undet. sp. 4	0	0	1
Rhaphidophoridae	<i>Gammarotettix bilobatus</i> Thomas	20	6	12
Gryllidae	<i>Hoplosphyrum</i> sp.	2	0	1
	<i>Oecanthus californicus</i> Saussure	1	9	8
	undet. sp. 3	1	1	0
Dermaptera				
Forficulidae	<i>Forficula auricularia</i> L.	5	2	8
Plecoptera				
Undetermined	undet. sp. 1	1	0	4
	undet. sp. 2	0	0	2
	undet. sp. 3	0	0	1
Psocoptera				
Trogiidae	<i>Cerobasis guestfalica</i> (Kolbe)	29	14	21
Liposcelididae	<i>Liposcelis</i> sp.	2	0	1
Caeciliidae	<i>Caecilius burmeisteri</i> Brauer	3	0	4
	<i>Caecilius maritimus</i> Mockford	5	14	42
	<i>Caecilius</i> sp. 3	1	1	1
	<i>Caecilius</i> sp. 4	5	0	0
	undet. sp. 5	0	0	1
Amphipsocidae	<i>Polypsocus corruptus</i> (Hagen)	0	1	4
Dasydemellidae	<i>Teliapsocus conterminus</i> (Walsh)	2	0	1
Stenopsocidae	<i>Graphopsocus cruciatus</i> (L.)	30	52	167
Elipsocidae	<i>Elipsocus hyalinus</i> (Stephens)	4	5	4
Philotarsidae	<i>Philotarsus picicornis</i> (Fabricius)	1	6	2
Lachesillidae	<i>Lachesilla pacifica</i> Chapman	5	2	17
Peripsocidae	<i>Peripsocus subfasciatus</i> (Rambur)	1	0	0
Ectopsocidae	<i>Ectopsocus briggsi</i> McLachlan	87	75	396
	<i>Ectopsocus californicus</i> (Banks)	69	54	274
Trichopsocidae	<i>Trichopsocus acuminatus</i> Badonnel	18	27	108
Psocidae	<i>Amphigerontia bifasciata</i> (Latreille)	69	2	4
	<i>Indiopsocus</i> sp.	0	5	1
	<i>Loensia maculosa</i> (Banks)	23	1	1
	undet. sp. 4	0	0	9
Undetermined	undet. sp. 1	0	1	0
	undet. sp. 2	1	0	0
Heteroptera				
Tingidae	<i>Corythucha incurvata</i> Uhler	17	1	688
	undet. sp. 2	2	0	0
	undet. sp. 3	1	0	0
	undet. sp. 4	0	0	1
Miridae	<i>Engytatus</i> sp.	0	0	3
	<i>Irbisia</i> sp. 1	1	17	0

Appendix 1. Continued.

Order Family	Species	C	P	T
	<i>Parthenicus brunneus</i> Van Duzee	423	0	1
	<i>Plagiognathus diversus cruralis</i> Van Duzee	0	58	0
	undet. sp. 1	80	1	7
	undet. sp. 2	0	0	23
	undet. sp. 3	31	7	34
	undet. sp. 4	227	0	1
	undet. sp. 5	5	6	21
	undet. sp. 6	1	6	13
	undet. sp. 7	2	9	71
	undet. sp. 8	3	5	68
	undet. sp. 9	3	3	0
	undet. sp. 11	0	0	4
	undet. sp. 12	0	1	0
	undet. sp. 13	17	0	0
	undet. sp. 14	0	1	0
	undet. sp. 15	5	0	0
	undet. sp. 16	1	0	0
	undet. sp. 17	1	0	0
	undet. sp. 18	0	1	1
	undet. sp. 19	1	0	0
Nabidae	undet. sp.	1	0	0
Anthocoridae	<i>Orius insidiosus</i> (Say)	22	0	3
	undet. sp. 2	0	0	6
	undet. sp. 3	1	0	0
Reduviidae	<i>Empicoris rubromaculatus</i> (Blackburn)	0	0	7
	undet. immature sp. 2	1	2	3
Berytidae	undet. sp.	1	1	0
Lygaeidae	<i>Nysius tenellus</i> Barber	85	0	2
	undet. sp. 2	1	1	2
	undet. sp. 3	2	0	1
	undet. sp. 4	1	0	0
	undet. sp. 5	1	0	0
Rhopalidae	<i>Leptocoris trivittatus</i> (Say)	1	17	1
Pentatomidae	undet. sp. 1	0	1	0
	undet. sp. 2	0	0	2
	undet. sp. 3	0	0	1
	undet. sp. 4	4	0	0
	undet. sp. 5	0	0	1
Homoptera				
Cicadidae	undet. sp.	3	0	0
Membracidae	<i>Philya californiensis</i> (Goding)	809	0	1
	<i>Stictocephala</i> sp.	2	0	0
	undet. sp. 3	0	0	3
	undet. sp. 4	0	0	1
	undet. sp. 5	2	0	3
Aphrophoridae	undet. sp. 1	3	1	2
Cercopidae	undet. sp. 1	15	2	11
	undet. sp. 2	18	3	34
	undet. sp. 3	0	1	0
	undet. sp. 4	0	2	0
	undet. sp. 5	1	0	0
	undet. sp. 6	0	1	0

Appendix 1. Continued.

Order Family	Species	C	P	T
Cicadellidae	<i>Acroneura</i> sp.	0	13	0
	<i>Empoasca</i> sp. 1	759	4	6
	<i>Empoasca</i> sp. 2	134	1	3
	<i>Neocoelidiana obscura</i> (Baker)	8	0	6
	<i>Pagaronia tredecimpunctata</i> Ball	9	12	4
	<i>Stragania</i> sp.	7	0	0
	undet. sp. 7	8	0	0
	undet. sp. 8	1	0	0
	undet. sp. 9	1	0	0
	undet. sp. 10	1	0	0
	undet. sp. 11	3	0	0
	undet. sp. 12	1	0	0
	undet. sp. 13	1	3	0
	undet. sp. 14	1	0	0
	undet. sp. 15	1	0	0
	undet. sp. 16	1	0	0
	undet. sp. 17	0	1	0
	undet. sp. 18	0	0	1
	undet. sp. 19	1	0	0
	undet. sp. 20	0	0	3
	undet. sp. 21	1	0	1
	undet. sp. 22	1	0	0
	undet. sp. 23	1	0	0
	undet. sp. 24	0	2	0
	undet. sp. 25	0	1	0
	undet. sp. 26	1	1	2
	undet. sp. 27	1	0	0
	undet. sp. 28	1	0	0
	undet. sp. 29	2	1	0
	undet. sp. 30	2	0	1
	undet. sp. 31	2	0	0
	undet. sp. 32	0	0	1
	undet. sp. 33	0	1	0
	undet. sp. 34	1	0	0
	undet. sp. 35	0	0	2
	undet. sp. 36	2	0	0
	undet. sp. 37	0	2	1
	undet. sp. 38	0	0	1
	undet. sp. 39	0	0	1
	undet. sp. 40	1	0	1
	undet. sp. 41	3	3	2
	undet. sp. 42	1	0	6
Delphacidae	undet. sp.	3	0	0
Psyllidae	<i>Psylla</i> sp.	3	1	2
	undet. sp. 2	0	0	1
	undet. sp. 3	0	1	0
	undet. sp. 4	1	0	0
	undet. sp. 5	0	0	1
	undet. sp. 6	0	1	4
	undet. sp. 7	1	0	0
	undet. sp. 8	1	0	0
	undet. sp. 9	0	0	2

Appendix 1. Continued.

Order Family	Species	C	P	T
Aleyrodidae	undet. sp. 1	12	9	7
	undet. sp. 2	6	9	0
	undet. sp. 3	5	0	7
	undet. sp. 4	0	0	1
	undet. sp. 5	1	0	2
	undet. sp. 6	0	0	2
	undet. sp. 7	1	0	0
	undet. sp. 8	2	1	1
Aphidae	<i>Aphis baccharicola</i> Hille Ris Lambers	1383	10	1
	<i>Aphis</i> sp. 3	5	1	5
	<i>Aphis</i> sp. 4	15	2	0
	<i>Aphis spiraecola</i> Patch	15	0	2
	<i>Brachycaudus helichrysi</i> Kaltenbach	252	5	10
	<i>Dactynotus</i> sp. 1	42	7	6
	<i>Dactynotus</i> sp. 2	68	4	2
	<i>Hyadaphis foeniculi</i> Passerini	31	7	46
	<i>Myzocallis agrifolicola</i> Richards	7	4	15
	<i>Myzus persicae</i> Sulzer	45	1	0
	<i>Ovatus</i> sp.	14	5	5
	<i>Tuberculatus</i> sp. 1	5	1	3
	<i>Tuberculatus</i> sp. 2	0	4	5
	undet. sp. 1	7	1	2
	undet. sp. 2	14	3	0
	undet. sp. 14	0	3	1
	undet. sp. 15	3	0	0
	undet. sp. 16	0	0	1
	undet. sp. 17	7	0	0
	undet. sp. 18	1	1	1
	undet. sp. 19	0	2	2
	undet. sp. 20	0	0	2
	undet. sp. 21	2	0	1
	undet. sp. 22	3	0	2
	undet. sp. 23	0	3	0
	undet. sp. 24	2	35	0
	undet. sp. 25	0	4	0
	undet. sp. 26	7	0	0
	undet. sp. 27	2	0	0
	undet. sp. 28	1	0	0
	undet. sp. 29	1	0	0
	undet. sp. 30	1	0	0
	undet. sp. 31	0	0	1
	undet. sp. 32	3	0	0
Coccidae	<i>Ceroplastes</i> sp.	4	0	0
Triozidae	<i>Calinda longistylus</i> Crawford	77	0	0
Undetermined	male undet. scale sp. 1	1	0	0
	male undet. scale sp. 2	0	0	1
	male undet. scale sp. 3	1	0	0
	male undet. scale sp. 4	0	2	0
	male undet. scale sp. 5	1	0	0
	undet. scale sp. 1	1	0	0
	undet. scale sp. 2	1	0	0
	undet. scale sp. 3	6	0	0
	undet. scale sp. 4	1	1	0

Appendix 1. Continued.

Order Family	Species	C	P	T
	undet. scale sp. 5	0	0	10
	undet. scale sp. 6	0	0	5
	undet. scale sp. 7	0	0	2
	undet. scale sp. 8	0	0	1
	undet. sp. 1	0	0	1
	undet. sp. 2	2	0	1
Thysanoptera				
Aeolothripidae	<i>Aeolothrips</i> sp. 1	60	3	39
	<i>Aeolothrips</i> sp. 2	1	0	0
	<i>Franklinothrips</i> sp.	1	0	1
	<i>Melanothrips</i> sp.	0	1	1
	undet. sp. 2	3	2	5
	undet. sp. 6	1	1	0
Thripidae	<i>Anaphothrips</i> sp.	4	5	0
	<i>Chirothrips</i> sp.	4	1	0
	<i>Frankliniella</i> sp. 1	1060	102	18,397
	<i>Frankliniella</i> sp. 2	15	137	17
	<i>Heliothrips haemorrhoidalis</i> (Bouché)	0	11	98
	undet. sp. 2	5	11	61
	undet. sp. 3	73	1105	15
	undet. sp. 4	3	26	7
	undet. sp. 5	24	6	47
	undet. sp. 6	3	3	11
	undet. sp. 7	22	0	1
	undet. sp. 8	0	1	0
	undet. sp. 9	0	0	2
Phlaeothripidae	<i>Leptothrips</i> sp.	362	71	184
	<i>Nesothrips</i> sp.	1	0	0
	undet. sp. 2	5	4	386
	undet. sp. 3	1	3	0
	undet. sp. 4	1	0	0
	undet. sp. 5	0	1	1
Undetermined	undet. sp. 1	0	0	1
	undet. sp. 2	0	0	1
Neuroptera				
Raphidiidae	<i>Agulla</i> sp.	1	1	1
Coniopterygidae	<i>Coniopteryx latipalpus</i> Meinander	0	1	3
	<i>Coniopteryx palpalpus</i> Meinander	3	1	0
	other adult <i>Coniopteryx</i> spp.	7	2	11
	larva <i>Coniopteryx</i> spp.	28	1	13
		17	5	12
Hemerobiidae	<i>Hemerobius</i> sp. 1	1	0	2
		26	17	20
Chrysopidae	<i>Chrysoperla carnea</i> (Stephens)	0	0	1
	<i>Chrysoperla plorabunda</i> (Fitch)	6	0	3
	<i>Pseudomallada sierra</i> (Banks)	0	0	1
	chrysopid sp. 4	2	0	0
	chrysopid sp. 5			
Coleopterera				
Leiodidae	<i>Agathidium rotundulum</i> Mannerheim	3	0	38
Scydmaenidae	undet. sp. 1	7	2	9
	undet. sp. 2	6	0	4
	undet. sp. 3	3	3	2

Appendix 1. Continued.

Order Family	Species	C	P	T
Staphylinidae	<i>Pseudolesteva</i> sp.	0	28	0
	undet. sp. 2	0	2	0
	undet. sp. 3	0	0	2
	undet. sp. 4	1	0	0
	undet. sp. 5	0	0	1
	undet. sp. 6	0	0	1
	undet. sp. 7	1	0	0
Hydrophilidae	undet. sp.	1	0	1
Buprestidae	undet. sp. 1	2	0	0
Elateridae	<i>Limonium ornatulus</i> (LeConte)	0	5	6
	<i>Sericus silaceus</i> (Say)	1	10	0
	undet. sp. 3	0	0	1
	undet. sp. 4	0	10	0
	undet. sp. 5	1	0	0
	undet. sp. 6	1	0	0
	undet. sp. 7	1	0	0
	undet. sp. 8	0	0	1
	undet. sp. 9	0	0	1
Cantharidae	<i>Cantharis</i> sp. 1	0	10	2
	<i>Cantharis</i> sp. 2	3	1	1
	<i>Malthinus</i> sp.	0	2	0
	<i>Malthodes bicurvatus</i> Fall	5	7	5
	<i>Podabrus pruniosus</i> LeConte	4	0	1
	<i>Podabrus modulatus</i> Fall	6	0	3
	undet. sp. 7	0	0	1
	undet. sp. 8	1	1	0
Dermestidae	<i>Cryptorhopalum apicale</i> (Mannerheim)	3	16	6
	undet. sp. 2	1	0	0
Anobiidae	undet. sp. 1	0	0	1
	undet. sp. 2	1	0	0
	undet. sp. 3	5	0	0
	undet. sp. 4	2	0	0
	undet. sp. 5	0	1	0
	undet. sp. 6	1	0	1
	undet. sp. 7	1	0	0
	undet. sp. 8	0	1	0
	undet. sp. 9	0	0	1
Ptinidae	<i>Ptinus interruptus</i> LeConte	8	0	5
	undet. sp. 2	0	1	0
Cleridae	undet. sp. 3	3	0	1
	undet. sp. 1	0	2	1
	undet. sp. 2	0	0	1
	undet. sp. 3	1	1	0
Melyridae	undet. sp. 4	1	0	1
	<i>Collops vitattus</i> (Say)	0	2	2
	<i>Listrus canescens</i> (Mannerheim)	1	11	6
	undet. sp. 1	4	4	5
Coccinellidae	undet. sp. 2	1	1	9
	<i>Cephaloscymnus occidentalis</i> Horn	0	0	1
	<i>Chilocorus bipustulatus</i> (L.)	0	0	1
	<i>Chilocorus</i> nr. <i>orbus</i>	0	0	3
	<i>Coccinella californica</i> Mannerheim	3	1	1
	<i>Coccinella septempunctata</i> (L.)	1	0	1

Appendix 1. Continued.

Order Family	Species	C	P	T
	<i>Coccinella trifasciata subversa</i> LeConte	5	1	1
	<i>Cycloneda polita</i> Casey	5	2	3
	<i>Hippodamia convergens</i> Guerin	4	0	1
	<i>Hyperaspis quadrioculatus</i> Motschulsky	4	0	3
	<i>Psyllobora vigintimaculata</i> Say	80	7	21
	<i>Scymnus (Pullus) calaveras</i> Casey	0	0	2
	<i>Scymnus (Pullus) pallens</i> LeConte	0	1	5
	<i>Scymnus (Pullus)</i> sp. 1	10	1	1
	<i>Scymnus (Pullus)</i> sp. 2	15	0	0
	<i>Scymnus (Pullus)</i> sp. 3	1	0	1
	<i>Scymnus (Pullus)</i> sp. 4	1	0	0
	<i>Scymnus (Pullus)</i> sp. 5	0	1	1
	<i>Scymnus (Scymnus) nebulosus</i> LeConte	1	0	0
	<i>Scymnus marginicollis</i> Mannerheim	1	0	0
	<i>Stethorus punctum picipes</i> Casey	1	2	0
	<i>Zagloba ornata</i> (Horn)	1	0	10
	undet. larva sp. 1	57	5	1
	undet. larva sp. 2	1	0	2
	undet. larva sp. 3	1	0	0
	undet. larva sp. 4	2	0	0
	undet. larva sp. 5	1	4	0
	undet. larva sp. 6	0	0	2
	undet. sp. 22	0	0	2
Corylophidae	undet. sp. 1	1	0	0
	undet. sp. 2	1	0	0
Byturidae	<i>Byturellus grisescens</i> (Jayne)	4	3	6
Mordellidae	undet. sp. 1	0	1	0
	undet. sp. 2	0	0	2
	undet. sp. 3	1	0	2
	undet. sp. 4	0	0	1
	undet. sp. 5	1	0	2
	undet. sp. 6	0	0	12
	undet. sp. 7	0	0	1
Meloidae	undet. sp. 1	1	0	0
	undet. sp. 2	0	1	0
	undet. sp. 3	1	0	0
Anthicidae	<i>Anthicus nitidulus</i> LeConte	14	4	13
	undet. sp. 2	1	0	1
Cerambycidae	undet. larva sp. 1	0	1	0
	undet. sp. 1	0	0	1
	undet. sp. 2	0	0	1
Bruchidae	<i>Stator limbatus</i> (Horn)	10	3	1
	undet. sp. 2	3	0	0
	undet. sp. 3	1	0	0
	undet. sp. 4	0	0	2
	undet. sp. 5	0	0	1
Chrysomelidae	<i>Crepidodera</i> sp. 1	8	0	1
	<i>Cryptocephalus confluentus</i> White	3	0	0
	<i>Diabrotica undecimpunctata</i> Mannerheim	7	0	1
	<i>Diachus auratus</i> (Fabricius)	17	10	27
	<i>Epitrix hirtipennis</i> (Melsheimer)	0	68	2
	<i>Trirhabda flavolimbada</i> (Mannerheim) adult	14	0	0
	<i>Trirhabda flavolimbada</i> (Mannerheim) larva	71	0	0

Appendix 1. Continued.

Order Family	Species	C	P	T	
	undet. larva sp. 2	1	9	3	
	undet. larva sp. 3	0	0	2	
	undet. larva sp. 4	0	0	2	
	undet. larva sp. 5	0	0	1	
	undet. sp. 7	0	0	3	
	undet. sp. 8	0	0	5	
	undet. sp. 9	0	0	1	
	undet. sp. 10	1	0	0	
	undet. sp. 11	0	1	0	
	undet. sp. 12	1	0	0	
	undet. sp. 13	0	0	1	
	Brentidae	<i>Apion cribricolle</i> LeConte	11	0	9
	Curculionidae	<i>Sibinia maculata</i> (LeConte)	5	1	1
	undet. sp. 2	0	0	7	
	undet. sp. 3	1	0	1	
	undet. sp. 4	0	0	1	
	undet. sp. 5	0	1	0	
	undet. sp. 6	0	0	1	
	undet. sp. 7	1	0	0	
	undet. sp. 8	0	0	1	
	undet. sp. 9	0	0	1	
	undet. sp. 10	0	0	3	
	Undetermined	undet. sp. 1	0	0	4
	undet. sp. 2	0	0	1	
	undet. sp. 3	1	0	2	
	undet. sp. 4	0	0	1	
	undet. sp. 5	0	0	2	
	undet. sp. 6	0	0	1	
	undet. sp. 7	1	0	0	
	undet. sp. 8	1	0	0	
	undet. larva sp. 1	6	1	0	
	undet. larva sp. 2	0	0	1	
	undet. larva sp. 3	0	1	0	
	undet. larva sp. 4	0	0	2	
	undet. larva sp. 5	0	1	0	
	undet. larva sp. 6	2	1	0	
	undet. larva sp. 7	0	1	0	
	undet. larva sp. 8	1	3	0	
	undet. larva sp. 9	0	1	0	
undet. larva sp. 10	0	1	0		
Diptera					
Tipulidae	undet. sp. 1	0	0	1	
	undet. sp. 2	0	1	3	
Mycetophilidae	undet. sp.	0	0	1	
Sciaridae	<i>Lycoriella</i> sp.	2	0	2	
	undet. sp. 2	0	0	5	
	undet. sp. 3	3	0	1	
	undet. sp. 4	1	2	0	
	undet. sp. 5	0	2	0	
	undet. sp. 6	0	0	1	
	undet. sp. 7	1	0	0	
	undet. sp. 8	1	0	0	

Appendix 1. Continued.

Order Family	Species	C	P	T
Cecidomyiidae	<i>Contarinia</i> sp.	39	3	0
	<i>Cordylomyia</i> sp.	1	0	0
	<i>Lestremiinae</i> sp.	0	0	1
	<i>Polystepha</i> sp.	2	1	1
	<i>Porricondyla</i> sp.	1	2	8
	<i>Rhopalomyia californica</i> Felt	2	0	0
	undet. sp. 5	0	0	1
	undet. sp. 6	2	0	0
	undet. sp. 8	0	1	0
	undet. sp. 9	3	0	1
	undet. sp. 10	0	1	5
	undet. sp. 11	1	0	0
	undet. sp. 12	3	0	0
	undet. sp. 13	0	1	0
	undet. sp. 14	0	0	1
Scatopsidae	<i>Psectrosciara</i> sp.	0	0	2
Synneuridae	undet. sp.	1	0	0
Simuliidae	undet. sp. 1	0	0	1
	undet. sp. 2	1	0	0
Ceratopogonidae	undet. sp. 1	0	1	0
	undet. sp. 2	0	0	1
Chironomidae	<i>Orthocladius</i> sp.	28	3	6
	undet. sp. 2	7	3	3
	undet. sp. 3	17	1	34
	undet. sp. 4	0	0	1
	undet. sp. 5	0	0	1
	undet. sp. 6	1	0	0
	undet. sp. 7	1	2	0
	undet. sp. 8	0	1	0
	undet. sp. 9	1	0	0
	undet. sp. 10	1	0	0
	undet. sp. 11	2	0	1
	undet. sp. 12	1	0	0
	undet. sp. 13	1	0	0
Rhagionidae	undet. sp.	0	0	2
Empididae	undet. sp. 1	0	0	3
	undet. sp. 2	0	1	0
	undet. sp. 3	1	0	0
Dolichopodidae	undet. sp. 1	1	0	0
	undet. sp. 2	1	0	0
Phoridae	undet. sp. 1	1	0	0
	undet. sp. 2	0	0	1
	undet. sp. 3	1	0	0
Tephritidae	undet. sp. 1	1	0	0
	undet. sp. 2	2	0	0
Agromyzidae	undet. sp. 1	0	0	1
	undet. sp. 2	1	0	0
	undet. sp. 3	0	2	0
	undet. sp. 4	0	1	0
Asteiidae	undet. sp. 1	0	0	1
	undet. sp. 2	1	0	0
Lauxaniidae	undet. sp. 1	1	0	0
	undet. sp. 2	1	0	0

Appendix 1. Continued.

Order Family	Species	C	P	T
Trixoscelididae	undet. sp.	1	0	0
Chyromyidae	undet. sp.	0	0	1
Drosophilidae	undet. sp.	1	0	0
Chloropidae	undet. sp. 1	0	1	0
	undet. sp. 2	2	0	0
Undetermined	undet. larva sp. 1	0	0	1
	undet. larva sp. 2	0	1	0
Lepidoptera				
Lyonetiidae	<i>Bucculatrix variabilis</i> Braun (adult)	87	0	3
	<i>Bucculatrix variabilis</i> Braun (larva)	2265	1	4
Coleophoridae	<i>Coleophora lynosyridella</i> Walsingham	59	0	0
	<i>Coleophora viscidiflorella</i> Walsingham	313	1	0
Cossidae	undet. sp. 1	0	3	1
Tortricidae	undet. sp. 1	0	1	5
	undet. sp. 2	0	0	3
Pterophoridae	undet. sp. 1	0	1	0
	undet. sp. 2	0	1	0
Pyralidae	Phycitinae sp.	0	0	4
	undet. sp. 1	4	1	0
	undet. sp. 2	0	2	4
Hesperiidae	undet. sp. 1	0	0	4
Lycaenidae	undet. sp. 1	0	0	1
	undet. sp. 2	0	0	1
Geometridae	<i>Dichorda illustraria</i> (Hulst)	0	3	0
	<i>Elpiste marcescaria</i> Gueneé	314	1	2
	<i>Eupithecia rotundopuncta</i> Packard	2	3	1
	<i>Nematocampa limbada</i> (Haworth)	0	1	0
	<i>Nemoria leptalea</i> Ferguson	0	0	3
	<i>Nemoria</i> sp. 2	0	0	1
	<i>Neolcis californica</i> (Packard)	0	0	1
	<i>Prochoerodes truxaliata</i> Gueneé	8	0	0
	<i>Sabulodes aegrotata</i> (Gueneé)	7	9	11
	undet. sp. 1	0	4	1
	undet. sp. 2	1	0	6
	undet. sp. 3	46	8	8
	undet. sp. 4	4	0	0
	undet. sp. 5	2	0	0
	undet. sp. 6	3	0	0
	undet. sp. 7	1	0	0
	undet. sp. 8	3	0	1
	undet. sp. 9	3	0	0
	undet. sp. 10	1	0	0
	undet. sp. 11	0	4	0
	undet. sp. 12	0	1	0
	undet. sp. 13	0	1	0
	undet. sp. 14	0	1	0
	undet. sp. 15	0	1	0
	undet. sp. 16	0	1	0
	undet. sp. 17	0	0	2
	undet. sp. 18	0	0	2
	undet. sp. 19	0	0	1
	undet. sp. 20	0	0	1

Table 1. Continued.

Order Family	Species	C	P	T
Lymantriidae	undet. sp. 21	0	0	2
	undet. sp. 22	0	0	1
	<i>Orgyia leucostigma</i> (J. E. Smith)	0	0	1
	undet. sp. 2	1	0	1
Noctuidae	<i>Cosmia canescens</i> Behr.	0	0	1
Undetermined	undet. larva sp. 1	49	0	0
	undet. larva sp. 2	5	0	1
	undet. larva sp. 3	2	0	0
	undet. larva sp. 4	1	0	0
	undet. larva sp. 5	1	0	0
	undet. larva sp. 6	1	0	1
	undet. larva sp. 7	1	0	0
	undet. larva sp. 8	1	0	0
	undet. larva sp. 9	0	1	0
	undet. larva sp. 10	0	3	0
	undet. larva sp. 11	0	2	1
	undet. larva sp. 12	0	1	0
	undet. larva sp. 13	0	1	0
	undet. larva sp. 14	0	0	1
	undet. larva sp. 15	0	0	1
	undet. larva sp. 16	1	1	2
	undet. larva sp. 17	2	1	3
	undet. larva sp. 18	0	0	2
	undet. larva sp. 19	0	0	1
	undet. larva sp. 20	0	0	1
	undet. larva sp. 21	0	0	2
	undet. larva sp. 22	0	0	1
	undet. larva sp. 23	1	0	1
	undet. larva sp. 24	0	0	1
	undet. larva sp. 25	1	0	1
	undet. larva sp. 26	0	0	1
	undet. larva sp. 27	0	0	1
	undet. larva sp. 28	2	0	1
	undet. larva sp. 29	0	0	2
	undet. larva sp. 30	0	0	2
	undet. larva sp. 31	0	1	0
	undet. adult sp. 1	1	0	0
	undet. adult sp. 2	9	0	0
	undet. adult sp. 3	1	1	0
	undet. adult sp. 4	1	0	0
Hymenoptera				
Ceraphronidae	undet. sp. 1	1	0	0
	undet. sp. 2	0	0	1
	undet. sp. 3	0	0	1
	undet. sp. 4	0	0	3
	undet. sp. 5	0	1	0
	undet. sp. 6	0	0	1
Braconidae	undet. sp. 1	1	0	0
	undet. sp. 2	2	0	0
	undet. sp. 3	2	0	0
	undet. sp. 4	1	0	1
	undet. sp. 5	2	0	0

Appendix 1. Continued.

Order Family	Species	C	P	T
Ichneumonidae	undet. sp. 6	2	0	0
	undet. sp. 7	0	1	0
	undet. sp. 8	0	0	1
	undet. sp. 9	1	0	0
	undet. sp. 10	0	0	1
	undet. sp. 11	0	0	1
	undet. sp. 12	0	0	1
	undet. sp. 13	8	0	0
	undet. sp. 1	0	0	3
	undet. sp. 2	0	0	1
	undet. sp. 3	0	1	0
	undet. sp. 4	0	0	1
	undet. sp. 5	0	0	1
	undet. sp. 6	1	0	0
	undet. sp. 7	0	1	0
	undet. sp. 8	2	0	0
Mymaridae	Gonatocerinae sp. 1	2	0	0
	Gonatocerinae sp. 2	0	1	0
	Gonatocerinae sp. 3	0	1	0
	Gonatocerinae sp. 4	0	0	1
	Gonatocerinae sp. 5	1	0	0
	Gonatocerinae sp. 6	1	0	0
	Mymarinae sp. 1	7	3	1
	Mymarinae sp. 2	1	0	1
	Mymarinae sp. 3	5	1	2
	Mymarinae sp. 4	4	0	0
	Mymarinae sp. 5	0	1	0
	Mymarinae sp. 6	0	0	1
	Mymarinae sp. 7	1	0	0
	undet. sp. 3	4	0	1
Trichogrammatidae	undet. sp. 1	1	0	0
	undet. sp. 2	0	0	1
Eulophidae	Tetrastichinae sp. 1	1	2	4
	Tetrastichinae sp. 2	3	4	3
	Tetrastichinae sp. 3	1	0	1
	Tetrastichinae sp. 4	2	1	2
	Tetrastichinae sp. 5	1	0	0
	Tetrastichinae sp. 6	1	0	0
	Tetrastichinae sp. 7	0	1	0
	Tetrastichinae sp. 8	0	0	1
	Tetrastichinae sp. 9	1	0	0
	Tetrastichinae sp. 10	0	1	0
	Tetrastichinae sp. 11	1	0	0
	undet. sp. 1	3	0	0
	undet. sp. 2	5	0	0
	undet. sp. 3	8	0	0
	undet. sp. 4	5	0	0
	undet. sp. 5	0	1	1
	undet. sp. 6	4	0	0
	undet. sp. 7	0	2	0
	undet. sp. 8	1	0	0
	undet. sp. 9	0	2	5
	undet. sp. 10	0	0	3

Appendix 1. Continued.

Order Family	Species	C	P	T
	undet. sp. 11	0	0	2
	undet. sp. 12	0	0	1
	undet. sp. 13	0	0	1
	undet. sp. 14	0	1	0
	undet. sp. 15	0	0	1
	undet. sp. 16	1	0	0
	undet. sp. 17	0	0	1
	undet. sp. 18	3	0	0
	Elasmidae undet. sp. 1	1	0	0
	undet. sp. 2	1	0	0
Aphelinidae	undet. sp. 1	2	4	1
	undet. sp. 2	2	0	5
	undet. sp. 3	0	0	1
	undet. sp. 4	0	1	0
	undet. sp. 5	0	0	1
Signiphoridae	undet. sp. 6	1	0	0
	undet. sp. 1	0	1	1
	undet. sp. 2	1	0	0
	undet. sp. 3	0	1	0
Encyrtidae	undet. sp. 1	4	1	1
	undet. sp. 2	0	0	4
	undet. sp. 3	2	0	0
	undet. sp. 4	2	0	3
	undet. sp. 5	4	0	0
	undet. sp. 6	2	0	2
	undet. sp. 7	2	0	1
	undet. sp. 8	2	0	2
	undet. sp. 9	1	1	0
	undet. sp. 10	1	0	0
	undet. sp. 11	1	1	0
	undet. sp. 12	1	1	0
	undet. sp. 13	1	0	1
	undet. sp. 14	1	0	0
	undet. sp. 15	1	0	0
	undet. sp. 16	1	0	0
	undet. sp. 17	1	0	0
	undet. sp. 18	1	0	0
	undet. sp. 19	0	1	0
	undet. sp. 20	2	0	0
	undet. sp. 21	1	0	0
	undet. sp. 22	1	0	0
	undet. sp. 23	0	1	0
	undet. sp. 24	1	0	0
	undet. sp. 25	1	0	0
	undet. sp. 26	0	0	1
	undet. sp. 27	1	0	0
	undet. sp. 28	0	1	0
	undet. sp. 29	1	0	0
	undet. sp. 30	1	0	0
	undet. sp. 31	1	0	0
Eupelmidae	Eupelminae sp. 0	0	0	1
	Eupelminae sp. 1	0	1	0
	Eupelminae sp. 2	4	0	0

Appendix 1. Continued.

Order Family	Species	C	P	T
Torymidae	Eupelminae sp. 3	2	0	0
	Eupelminae sp. 4	3	0	0
	Eupelminae sp. 5	7	0	0
	Eupelminae sp. 6	3	0	0
	Eupelminae sp. 7	1	0	0
	Calosotinae sp. 1	2	0	0
	Calosotinae sp. 2	1	0	0
	Toryminae sp. 1	3	0	0
	Toryminae sp. 2	1	0	0
	Toryminae sp. 3	1	0	0
Pteromalidae	undet. sp. 1	6	0	1
	Brachyscelidiphaginae sp.	43	0	0
	Eunotinae sp.	3	0	0
	undet. sp. 1	12	0	0
	undet. sp. 3	7	0	0
	undet. sp. 4	22	0	0
	undet. sp. 5	8	0	0
	undet. sp. 6	14	0	0
	undet. sp. 7	6	0	0
	undet. sp. 8	5	0	0
	undet. sp. 9	3	0	0
	undet. sp. 10	5	0	0
	undet. sp. 11	1	0	1
	undet. sp. 13	1	1	1
	undet. sp. 14	2	0	0
	undet. sp. 15	0	1	0
	undet. sp. 16	0	1	0
	undet. sp. 17	1	1	0
	undet. sp. 18	1	0	1
	undet. sp. 19	1	0	1
	undet. sp. 20	0	1	1
	undet. sp. 21	2	0	0
	undet. sp. 22	1	0	0
	undet. sp. 23	0	0	1
	undet. sp. 24	0	0	1
	undet. sp. 27	1	0	0
	undet. sp. 28	1	0	0
	undet. sp. 29	0	1	0
Eurytomidae	Eurytominae sp. 1	1	0	0
	Eurytominae sp. 2	0	1	0
	Harmolitinae sp.	1	0	0
Chalcididae	Brachymeriinae sp.	0	1	0
Cynipidae	undet. sp. 1	2	7	1
	undet. sp. 2	0	1	1
	undet. sp. 3	1	0	2
	undet. sp. 4	0	1	0
	undet. sp. 5	0	0	1
	undet. sp. 6	0	1	0
Diapriidae	undet. sp. 1	1	0	1
	undet. sp. 2	0	0	1
	undet. sp. 3	0	0	1
Scelionidae	undet. sp. 1	1	0	0
	undet. sp. 2	0	0	1

Appendix 1. Continued.

Order Family	Species	C	P	T
Platygastridae	undet. sp. 1	197	2	1
	undet. sp. 2	3	6	3
	undet. sp. 3	0	1	4
	undet. sp. 4	30	2	1
	undet. sp. 5	1	0	1
	undet. sp. 6	0	1	1
	undet. sp. 7	0	0	1
	undet. sp. 8	1	0	0
	undet. sp. 9	0	1	0
	undet. sp. 10	0	1	0
	undet. sp. 11	0	0	4
Bethylidae	undet. sp. 1	0	3	0
	undet. sp. 2	1	3	0
	undet. sp. 3	1	0	0
Halictidae	undet. sp. 1	0	0	1
Tiphiidae	undet. sp. 1	0	1	0
Formicidae	<i>Camponotus hyatti</i> Emery	15	1	8
	<i>Camponotus vicinus</i> Mayr	14	0	0
	<i>Camponotus</i> sp. 3	0	1	0
	<i>Camponotus</i> sp. 4	0	0	1
	<i>Camponotus</i> sp. 5	0	0	1
	<i>Camponotus</i> sp. 6	1	0	0
	<i>Camponotus</i> sp. 7	1	0	0
	<i>Crematogaster coarctata</i> Mayr	236	16	33
	<i>Formica moki</i> Wheeler	46	2	2
	<i>Formica</i> sp. 2	2	4	8
	<i>Formica</i> sp. 3	112	0	0
	<i>Formica</i> sp. 4	2	0	0
	<i>Formica</i> sp. 5	1	0	0
	<i>Formica</i> sp. 6	1	0	0
	<i>Formica</i> sp. 7	0	0	1
	<i>Formica</i> sp. 8	1	0	0
	<i>Formica</i> sp. 9	0	3	0
	<i>Leptothorax gallae</i> M. Smith	1	3	1
	<i>Leptothorax</i> sp. 1	0	3	1
	<i>Leptothorax</i> sp. 2	0	2	1
	<i>Leptothorax</i> sp. 3	0	1	0
	<i>Leptothorax</i> sp. 4	1	0	0
	<i>Leptothorax</i> sp. 5	1	0	0
	<i>Linepithema humile</i> (Mayr)	1738	21	98
	<i>Monomorium ergatogyna</i> Wheeler	77	6	0
	<i>Monomorium</i> sp. 2	0	0	1
	<i>Prenolepis imparis</i> (Say)	132	156	185
	<i>Tapinoma sessile</i> (Say)	131	25	2
	undet. sp. 29	0	0	2
	undet. sp. 30	0	1	0
	undet. sp. 31	0	0	1
	undet. sp. 32	0	0	1
Undetermined	undet. sawfly larva sp. 1	1	1	1
	undet. sawfly larva sp. 2	0	1	0
	undet. chalcidoid sp. 1	1	0	0
	undet. chalcidoid sp. 2	0	0	1

Appendix 1. Continued.

Order Family	Species	C	P	T
	undet. chalcidoid sp. 3	1	0	0
	undet. chalcidoid sp. 4	0	0	3
	undet. wasp sp. 1	1	0	0
	undet. wasp sp. 2	1	0	0

PROCEEDINGS OF THE PACIFIC COAST ENTOMOLOGICAL SOCIETY, 2001

FIVE HUNDRED SEVENTY-SECOND MEETING

The 572nd meeting of the Pacific Coast Entomological Society was held at 8:00 PM on 14 December 2001, in the Goethe Room of the California Academy of Sciences in San Francisco with Mr. Stanley E. Vaughn presiding.

The following persons were introduced as guests: Mr. David Baumgardner by Dr. Norman D. Penny; Dr. Rob E. Roughley, a dytiscid specialist from the University of Manitoba, by Mr. Keve J. Ribardo; Dr. Catherine V. Milton of UC Berkeley by Dr. Paul H. Arnaud Jr.; and Dr. Elizabeth McGee of San Jose State University, David and Michele Vaughn, Lucille Mason, Lindsey Vaughn, and Jeffery Mills by Mr. Stanley E. Vaughn. Mr. Vaughn also recognized and welcomed Mike Solari, wishing him a happy 16th birthday.

The following new slate of officers was voted on and approved by the society: Dr. Rolf L. Aalbu for President-elect, Dr. Robert L. Zuparko for Treasurer, Mr. Vincent F. Lee for Managing Secretary, and Dr. Katherine N. Schick for President. Mr. Vaughn then handed over the gavel to Dr. Schick, who presided over the remainder of the meeting.

The membership committee announced that the 2001 membership was currently 329 members, including the 32 new members added this year.

Mr. Gordon Nishida of Salinas, California was proposed and approved as a regular member of the society.

The featured speaker, Mr. Stanley E. Vaughn, Curator of the Dr. J. Gordon Edwards Entomology Museum at San Jose State University, presented a blood-letting slide lecture entitled "Hippoboscids of Madagascar Lemurs." Aside from being another one of Mr. Vaughn's legendary entomological fables of biting, stinging, hurting and bleeding, the talk updated the audience on his work with Elizabeth McGee in the Ranomafana National Park. In this ideal land of medical entomology, Mr. Vaughn surveyed three species of lemurs in primary and secondary rainforests, assessing the lemurs for ectoparasite loads, with the long-term objective to assess the health risk associated with human and prosimian contact in disturbed ecosystems. During his work in the park, he attempted to determine how *Allobosca crassipes* (Speiser) find their hosts after pupating on the terrain. One possibility is they fly and then sheer off their wings once a host is acquired. *Allobosca* spp. are very host specific, with a life cycle that is still not fully understood, and no males have yet been described. Mr. Vaughn, now armed with 154 specimens of *Allobosca* spp., will continue research under better lab conditions.

The meeting was adjourned at 9:17 PM, followed by a social hour held in the Department of Entomology conference room.

The following 36 persons were present: (22 members) P. H. Arnaud Jr., R. M. Brown, H. K. Court, J. G. Edwards, J. J. Fairbanks, L. R. Faziola, E. M. Fisher, S. D. Gaimari, C. E. Griswold, D. K. James, V. F. Lee, T. C. Meikle, D. A. Parks, N. D. Penny, W. W. Pitcher, A. E. Rackett, K. J. Ribardo, W. E. Savary, K. N. Schick, J. J. Schweikert, M. Solari, and S. E. Vaughn; (14 guests) B. Bianchini, D. Baumgardner, M. Delmas, L. J. Mason, E. McGee, J. Mills, K. Milton, J. Myatt, A. Myatt, R. Roughley, D. Silva, D. S. Vaughn, L. Vaughn, and M. Vaughn.

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Ferrari, J. A. & K. S. Rai. 1989. Phenotypic correlates of genome size variation in *Aedes albopictus*. Evolution, 42: 895–899.
Sorensen, J. T. (in press). Three new species of *Essigella* (Homoptera: Aphididae). Pan-Pacif. Entomol.

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